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100 Area Source Operable Operable Unit Focused Feasibility Study Report

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EXECUTIVE SUMMARY

In accordance with the Hanford Past-Practice Strategy (HPPS), focused feasibility study (FFS) are performed for those waste sites which have been identified as candidates for interim remedial measure (IRM) based on information contained in applicable work plans and limited field investigations (LFI). The FFS constitutes the Phase 3 (detailed analysis) portion of the feasibility study (FS) process for the remedial alternatives initially developed and screened in the *100 Area Feasibility Study Phases 1 and 2* (hereinafter FS Phases 1 and 2) (DOE-RL 1993a). Note that the scope of this document is limited to 100 Area source operable units. Impacted groundwater beneath the 100 Area is being addressed in separate FFS. In addition, low priority sites and potentially impacted river sediments proximate to the 100 Area are not considered candidates for IRM, accordingly, they are being addressed under the remedial investigation (RI)/FS pathway of the HPPS.

As shown in Figure ES-1, the FFS process for the 100 Area source operable units will be conducted in two stages. This report, hereafter referred to as the Process Document, documents the first stage of the process. In this stage, IRM alternatives are developed and analyzed on the basis of waste site groups associated with the 100 Area source operable units. The second stage, site-specific evaluation of the IRM alternatives presented in this Process Document, is documented in a series of operable unit-specific reports.

The objective of the FFS (this Process Document and subsequent operable unit-specific reports) is to provide decision makers with sufficient information to allow appropriate and timely selection of IRM for sites associated with the 100 Area source operable units. Accordingly, the following information is presented herein:

- a presentation of remedial action objectives (based on a future recreational land-use)
- a description of 100 Area waste site groups and associated group profiles
- a description of IRM alternatives
- detailed and comparative analyses of the IRM alternatives

The six general response actions, and corresponding remedial alternatives identified in the FS Phases 1 and 2 are presented as follows:

- No Interim Action: Alternatives SS-1 and SW-1
- Institutional Controls: Alternatives SS-2 and SW-2
- Containment: Alternatives SS-3 and SW-3
- Removal/Disposal: Alternatives SS-4 and SW-4
- In Situ Treatment: Alternatives SS-8A, SS-8B, and SW-7
- Removal/Treatment/Disposal: Alternatives SS-10 and SW-9.

Table ES-1 provides a comprehensive list of the technologies included in each of the alternatives as well as a comparison of the applicability of these alternatives with respect to the waste site groups.

A detailed and comparative analysis is performed for these alternatives and waste site groups based on the nine Comprehensive Environmental Response, Compensation, and Liability Act of 1980 evaluation criteria. These evaluation criteria serve as the bases for conducting the detailed and comparative analyses during the FFS and for selection of the remedial action. The first two criteria, overall protection of human health and the environment and compliance with applicable relevant and appropriate requirements (ARAR), are termed threshold criteria. Alternatives that do not protect human health and the environment or do not comply with ARAR do not meet the statutory requirements for selection of a remedy; and therefore, are eliminated from further consideration. The next five criteria, long-term effectiveness and permanence; reduction of toxicity, mobility, or volume; short-term effectiveness; implementability; and cost; are balancing criteria. These elements are addressed to provide a consistent basis for evaluation of each alternative. The final two criteria, regulatory (federal and state agency) and community acceptance, are evaluated following the appropriate comment period. Table ES-2 provides a summary of the comparative analysis of the applicable alternatives for each waste site group.

Although single alternatives may be applied to the initial IRM, a combination of alternatives may be preferable as more information is gathered through the observational approach. The results of this Process Document on operable unit-specific FFS will be used in combination with information gathered during initial IRM implementation to evaluate the appropriate alternative or combination of alternatives.

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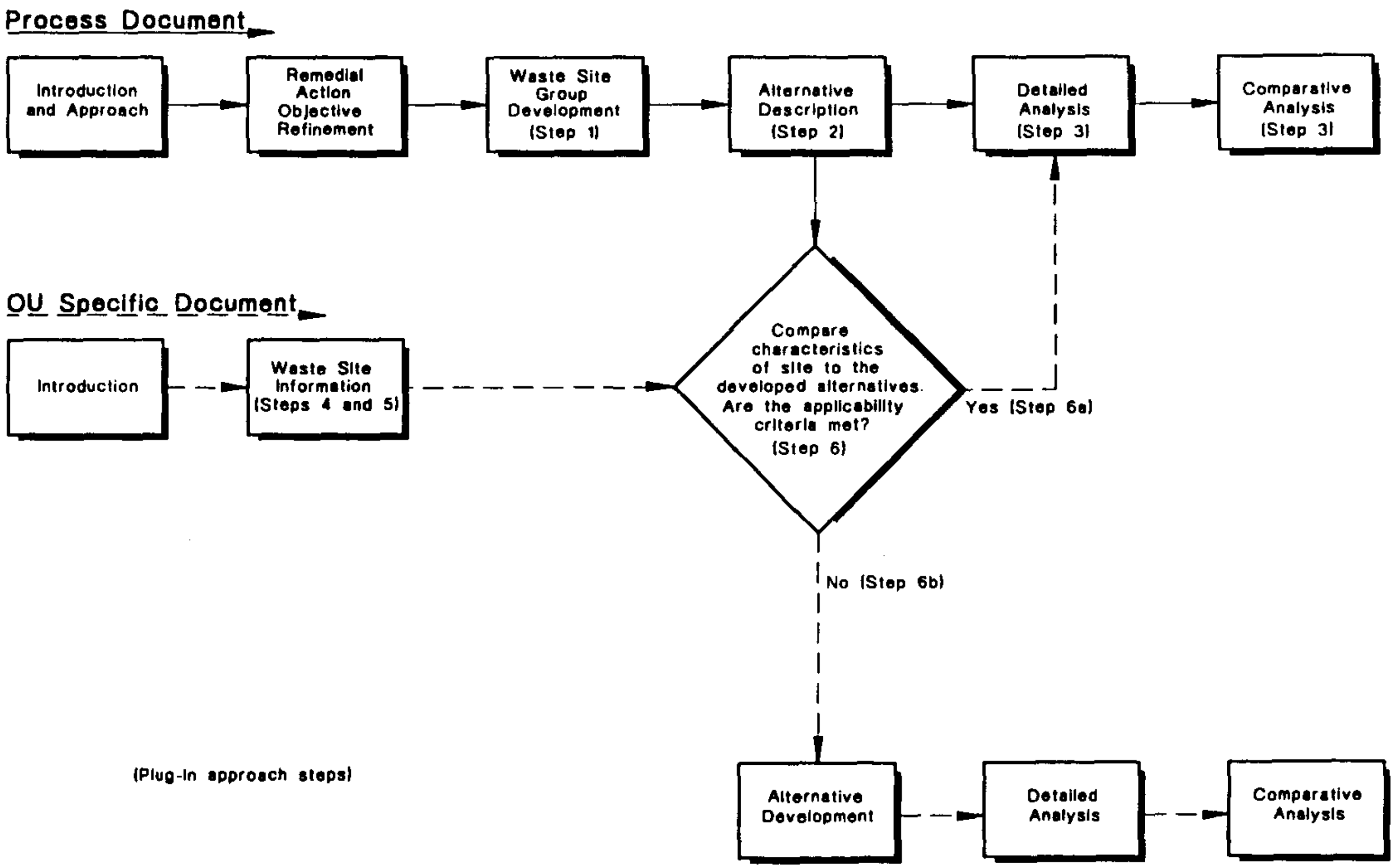

Figure ES-1 100 Area Source Operable Unit FFS Process

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Table ES-1 Soil and Solid Waste Site Group Remedial Alternatives and Technologies

Alternatives		Technologies Included	Waste Site Group									
			Retention Basins	Sludge Trenches	Fuel Storage Basin Trenches	Process Effluent Trenches	Pluto Cribs	Decon Cribs/ French Drains	Seal Pit Cribs	Pipelines	Burial Grounds	D&D Facilities
No Action	SS-1 SW-1	None										X
Institutional Controls	SS-2 SW-2	Deed Restrictions							X			
		Groundwater Monitoring							X			
Containment	SS-3 SW-3	Surface Water Controls						X		X	X	
		Modified RCRA Barrier						X		X	X	
		Deed Restrictions						X		X	X	
		Groundwater Monitoring						X		X	X	
Removal, Disposal	SS-4 SW-4	Removal	X	X	X	X	X	X		X	X	
		Disposal	X	X	X	X	X	X		X	X	
In Situ Treatment	SS-8A	Surface Water Controls		X		X	X	X				
		In Situ Vitrification		X		X	X	X				
		Groundwater monitoring		X		X	X	X				
		Deed restrictions		X		X	X	X				
	SS-8B	Void Grouting								X		
		Modified RCRA Barrier								X		
		Surface Water Controls								X		
		Deed Restrictions								X		
		Groundwater Monitoring								X		
	SW-7	Dynamic Compaction									X	
		Modified RCRA Barrier									X	
		Surface Water Controls									X	
		Groundwater Monitoring									X	
		Deed Restrictions									X	
Removal, Treatment, Disposal	SS-10	Removal	X	X	X	X	X	X		X		
		Thermal Desorption										
		Soil Washing	X	X	X	X	X	X		X		
		Disposal	X	X	X	X	X	X		X		
	SW-9	Removal									X	
		Thermal Desorption									X	
		Compaction									X	
		ERDF Disposal									X	

Note:
X - Technology applies to this Waste Site Group
blank - Technology does not apply to this Waste Site Group
D&D - Decontaminated and Decommissioned
RCRA - Resource Conservation and Recovery Act
ERDF - Environmental Restoration Disposal Facility

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Table ES-2 Comparative Analysis Summary

Comparative Analysis Summary[1]

Evaluation Criteria	Waste Site Groups (Table Reference)	Retention Basins (Table 6-1)		Sludge Trenches (Table 6-2)			Fuel Storage Basin Trenches (Table 6-3)		Process Effluent Trenches (Table 6-4)			Pluto Cribs (Table 6-5)			Dummy Decontamination Cribs and French Drains (Table 6-6)				Pipelines (Table 6-7)				Burial Grounds (Table 6-8)			
	Alternatives[2]	SS-4	SS-10	SS-4	SS-8A	SS-10	SS-4	SS-10	SS-4	SS-8A	SS-10	SS-4	SS-8A	SS-10	SS-3	SS-4	SS-8A	SS-10	SS-3	SS-4	SS-8B	SS-10	SW-3	SW-4	SW-7	SW-9
Overall Protection of Human Health and Environment		Better	Best	Better	Good	Best	Better	Best	Better	Good	Best	Better	Good	Best	Fair	Better	Good	Best	Poor	Better	Fair	Best	Fair	Better	Good	Best
Compliance with ARAR[3]		Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best
Long-Term Effectiveness and Permanence		Better	Better	Better	Good	Better	Better	Better	Better	Good	Better	Better	Good	Better	Fair	Better	Good	Better	Fair	Best	Better	Best	Fair	Best	Better	Best
Reduction of Toxicity, Mobility, and Volume		Poor	Better	Poor	Best	Better	Poor	Better	Poor	Best	Better	Poor	Best	Better	Poor	Fair	Best	Better	Fair	Good	Best	Better	Fair	Good	Best	Better
Short-Term Effectiveness		Best	Better	Better	Best	Good	Best	Better	Better	Best	Good	Better	Best	Good	Best	Good	Better	Fair	Best	Good	Better	Fair	Best	Good	Better	Fair
Implementability		Best	Good	Best	Fair	Good	Best	Good	Best	Fair	Good	Best	Fair	Good	Best	Better	Fair	Good	Best	Good	Good	Fair	Best	Better	Fair	Good
Present Worth[4] (millions $)		96	114	1.7	5.6	2.3	4.5	5.6	15.7	54.8	17.9	0.27	0.66	0.69	0.45	0.28	0.72	0.71	55	33	8.9	40	1.5	2.4	1.7	2.5

Notes:

1. Comparative Analysis Summary is based on Tables 6-1 through 6-8. Comparisons are made between relevant alternatives for each individual waste site group only.
2. Alternatives are summarized from Table 5-1.
   - SS-3/SW-3 Containment
   - SS-4/SW-4 Removal & Disposal
   - SW-7 In Situ Treatment of Solid Waste
   - SS-8A In Situ Treatment of Soils (except pipelines)
   - SS-8B In Situ Treatment of Soils (pipelines)
   - SW-9 Removal, Treatment, & Disposal of Solid Waste
   - SS-10 Removal, Treatment, & Disposal of Soil
3. ARAR - applicable or relevant and appropriate requirement
4. Cost is present worth at 5% discount rate.

Key:
- Best
- Better
- Good
- Fair
- Poor

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ACRONYMS

APWA	American Public Works Association
ARAR	applicable relevant and appropriate requirements
ARCL	allowable residual contamination levels
BFS	blast furnace slag
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
COPC	contaminants of potential concern
CRDL	contract required detection limit
CRQL	contract required quantitation limit
D&D	decontamination and decommissioning
DCG	Derived Concentration Guides
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
EM	Environmental Management
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
FFS	focused feasibility study
FS	feasibility study
GPR	ground penetrating radar
GRA	general response actions
HDPE	high-density polyethylene
HPPS	Hanford Past-Practice Strategy
HQ	hazard quotient
HRA	Hanford Remedial Action
HSBRAM	Hanford Site Baseline Risk Assessment Methodology
IBW	Indian Bend Wash
IRM	interim remedial measures
IROD	Interim Record of Decision
ISV	in situ vitrification
JHCM	joule-heated ceramic melter
LFI	limited field investigation
MCL	maximum contaminant levels
MT	metric tons
MTCA	Model Toxics Control Act
MWMF	Mixed Waste Management Facility
NEPA	National Environmental Policy Act
NPL	National Priorities List
NRDWL	Nonradiological Dangerous Waste Landfill
OTD	Office of Technology Development
PRG	preliminary remediation goals
QRA	qualitative risk assessment
RAO	remedial action objective

ACRONYMS (cont)

RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI	remedial investigation
ROD	record of decision
SVOC	semivolatile organic compounds
TBC	to-be-considered
TCLP	toxicity characteristic leaching procedure
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
TRU	transuranic
VOC	volatile organic compounds
WAC	Washington Administrative Code

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CONTENTS (cont)

CONTENTS (cont)

FIGURES:

TABLES:

CONTENTS (cont)

TABLES (cont):

1.0 INTRODUCTION

Four areas of the Hanford Site (the 100, 200, 300, and 1100 Areas) have been included on the U.S. Environmental Protection Agency's (EPA) National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) (Figure 1-1). Under the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1990), signed by the Washington State Department of Ecology (Ecology), EPA, and the U.S. Department of Energy (DOE), more than 1,000 inactive waste disposal and unplanned release sites on the Hanford Site have been grouped into a number of source and groundwater operable units. These operable units contain contamination in the form of hazardous waste, radioactive/hazardous mixed waste, and other CERCLA hazardous substances. The Tri-Party Agreement requires that the cleanup programs at the Hanford Site integrate the requirements of CERCLA, Resource Conservation and Recovery Act (RCRA), and Washington State's dangerous waste (the state's RCRA-equivalent) program.

Due to the complexity of the operable units at the Hanford Site, signatories to the Tri-Party Agreement developed an integrated CERCLA/RCRA site characterization and remediation strategy to comprehensively and expeditiously address environmental concerns associated with the Hanford Site. This strategy is known as the *Hanford Past-Practice Strategy* (HPPS) (DOE-RL 1991). The HPPS emphasizes integration of the results of ongoing site characterization activities into the decision making process at the earliest point practicable (observational approach) and expedites the remedial action process by emphasizing the use of interim actions. In accordance with the HPPS, this focused feasibility study (FFS) is being conducted to facilitate the selection of appropriate interim remedial measures (IRM) for candidate source sites in the 100 Areas. The HPPS, and the associated IRM pathway leading to the generation of 100 Area FFS documents, are presented graphically in Figure 1-2.

In accordance with DOE Order 5400.4 and Chapter 10 Code of Federal Regulations (CFR) Part 1021, the considerations (values) of the National Environmental Policy Act (NEPA) of 1969 are to be incorporated in the CERCLA process. The NEPA presents a tiered approach which allows area wide issues to be addressed in a common Environmental Impact Statement (EIS) with subsequent site-specific assessments incorporating pertinent information by reference alone (40 CFR 1502.20). The 100 Area FFS is compatible with this tiered approach; many of the NEPA considerations are addressed on a site-specific basis in the detailed analysis of IRM alternatives. However, Hanford Site and areawide impacts are addressed by the Hanford Remedial Action (HRA)-EIS. The HRA-EIS shall analyze the impacts caused by remediating the CERCLA/RCRA past-practice waste sites on the Hanford Site. A draft of the HRA-EIS is scheduled for public review in August, 1994. The final record of decision (ROD) for the HRA-EIS is scheduled for April, 1995.

The purpose and scope of this 100 Area FFS for the source operable units is presented in Section 1.1. A brief overview of the 100 Area and summary of associated Phases 1 and 2 Feasibility Study (FS) results are presented in Sections 1.2 and 1.3, respectively. Finally, an innovative approach to the FFS for the 100 Area source operable units is introduced in Section 1.4.

1.1 PURPOSE AND SCOPE

In accordance with the HPPS, FFS are performed for those operable units which have been identified as candidates for IRM based on information contained in applicable work plans and limited field investigations (LFI). The FFS constitutes the Phase 3 (detailed analysis) portion of the FS process for the remedial alternatives initially developed and screened in the *100 Area Feasibility Study Phases 1 and 2* (hereinafter FS Phases 1 and 2) (DOE-RL 1993a). Note that the scope of this document is limited to 100 Area source operable units. Impacted groundwater beneath the 100 Area is being addressed in separate operable unit-specific FFS. In addition, low priority sites and potentially impacted river sediments proximate to the 100 Area are not considered candidates for IRM, accordingly, they are being addressed under the final remedy selection pathway of the HPPS.

As shown in Figure 1-3, the FFS process for the 100 Area source operable units will be conducted in two stages. This report, hereafter referred to as the Process Document, documents the first stage of the process. In this stage, IRM alternatives are developed and analyzed on the basis of waste site groups associated with the 100 Area source operable units (e.g., retention basins, outfall structures). The second stage, site-specific evaluation of the IRM alternatives presented in this Process Document, is documented in a series of subsequent operable unit-specific reports.

The objective of the FFS (this Process Document and subsequent operable unit-specific reports) is to provide decision makers with sufficient information to allow appropriate and timely selection of IRM for sites associated with the 100 Area source operable units. Accordingly, the following information is presented herein:

- a brief description and historical overview of the 100 Area (Section 1.2)
- a summary of the FS Phases 1 and 2 results applicable to the 100 Area source operable units (Section 1.3)
- an introduction to, and description of, an innovative, streamlined FFS process developed for large multi-source "sites" such as the 100 Area. This process, designated the plug-in approach, is employed in this document and is discussed in further detail in Section 1.4
- a presentation of remedial action objectives for the 100 Area source operable units (Section 2.0)
- a description of 100 Area waste site groups and associated group profiles (Section 3.0)

- a description of IRM alternatives (Section 4.0)
- detailed and comparative analyses of the IRM alternatives (Sections 5.0 and 6.0 respectively).

1.2 100 AREA OVERVIEW

The 100 Area is one of four areas at the Hanford Site (the 100, 200, 300, and 1100 Areas) that have been included on the EPA's NPL under CERCLA. The 100 Area is located in the north-central part of the Hanford Site along the southern shoreline of the Columbia River (Figure 1-1). The 100 Area takes up approximately 26.6 square miles of land (DOE-RL 1992a).

Between 1943 and 1962, nine water-cooled, graphite-moderated plutonium production reactors were built along the shore of the Columbia River upstream from the now-abandoned town of Hanford. Eight of these reactors (B, C, D, DR, F, H, KE, and KW) are retired from service and are under evaluation for decommissioning. The ninth reactor, N, has been put into dry layup and will be retired.

Former waste disposal practices associated with operations of the 100 Area Reactors resulted in releases of radionuclides and other chemicals to soil and groundwater in the vicinity of the reactors. The primary source of these constituents was cooling water which flowed through the reactor core. The spent cooling water often contained radionuclides. As a result of leaks in the reactor effluent transfer systems and intentional effluent disposal in cribs and trenches, soil and underlying groundwater have been impacted. In addition, solid wastes containing radionuclides were buried in unlined trenches.

In accordance with the HPPS, high priority sites in the 100 Area have been placed in the IRM pathway. Continuation of these sites on the IRM pathway are documented in applicable 100 Area LFI reports. The definition/evaluation of IRM alternatives applicable to the high priority source sites in the 100 Area is the subject of this, and subsequent operable unit-specific documents.

1.3 SUMMARY OF 100 AREA FEASIBILITY STUDY PHASES 1 AND 2

The initial alternative development and screening components of the FS process for the 100 Area are documented in the FS Phases 1 and 2 (DOE-RL 1993a). Additional information contained in the FS Phases 1 and 2 included preliminary identification of potential applicable or relevant and appropriate requirements (ARAR), remedial action objectives (RAO), and general response actions (GRA).

General response actions applicable to mitigation of the concerns associated with the 100 Area were identified as follows:

- No Interim Action
- Institutional Actions
- Containment Actions
- Removal/Disposal Actions
- In Situ Treatment Actions
- Removal/Treatment/Disposal Actions.

Technologies and process options for each GRA component were then evaluated and assembled into remedial alternatives.

The ARAR and RAO identified in the Phase 1 and 2 FS (DOE-RL 1993a) are subsequently refined based on the evaluation of additional operable unit- and waste site-specific information gathered in the LFI (Section 2.0). In addition, the alternatives developed in the Phase 1 and 2 FS are refined accordingly and subjected to detailed analysis in accordance with CERCLA methodology (EPA 1988) and the plug-in approach subsequently described.

1.4 FOCUSED FEASIBILITY STUDY APPROACH

Due to the large number of similar contaminant sources or sites associated with the 100 Area, an innovative approach to alternative development and evaluation has been adopted for this FFS. The approach, termed the "plug-in approach", and its compatibility with the "analogous site" approach to site characterization outlined in the HPPS, are subsequently discussed.

The plug-in approach to FS was first documented in 1993 by EPA Region IX for the Indian Bend Wash (IBW) Superfund Site in Tempe, Arizona (EPA 1993). The need for a specialized approach to the FS for the IBW site was due to the large number (approximately 70) of similar yet individual source areas contained within the site. The source areas at IBW all exhibited volatile organic compounds (VOC) contamination of vadose zone soils. Traditional remedial investigation (RI)/FS methodology would dictate that these source areas be fully characterized prior to initiation of the remedy selection process. Because such an approach would have resulted in a large number of redundant FS (one for each source area) with attendant schedule and budget requirements, EPA developed the plug-in approach to preclude these undesired impacts on the IBW project. Briefly, the approach specifies and analyzes remedial alternatives for a group of sites which have similar characteristics (e.g., contaminants, impacted media). Once it is determined that an individual site is sufficiently similar to, or compatible with, a site group for which the alternatives have already been developed and analyzed, the subject site is said to "plug-in" to the analysis for that group.

Accordingly, the plug-in approach facilitates expeditious and cost effective remedy selection for applicable sites by eliminating the time, cost, and waste associated with the generation of multiple, redundant site-specific FS. For the purposes of this FFS the plug-in approach can be summarized as follows.

1) <u>Assemble Site Groups and Associated Group Profiles</u>

Assemble sites with similar characteristics (e.g., physical structure, function, and impacted media) into groups. These groups are based on the "analogous site" approach to site characterization discussed in the HPPS and shown in Figure 1-4. This FFS addresses the site groups identified in Figure 1-4, with the exception of the septic systems and special use burial grounds. These groups are not included because they are not represented by any current IRM candidate sites in the 100 Area. Specifically, the following site groups are evaluated in this Process Document:

- retention basins
- outfall structures
- pipelines
- process effluent trenches
- sludge trenches
- fuel storage basin trenches
- decontamination cribs/french drains
- pluto cribs
- seal pit cribs
- burial grounds
- decontamination and decommissioning (D&D) facilities.

Develop a description, or profile which is representative of the sites within each group. Such a description is called the *group profile.* Data used to generate the group profiles for each of the site groups were compiled from 100 Area operable unit LFI (i.e., 100-DR-1, 100-BC-1, and 100-HR-1 [DOE-RL 1993b, DOE-RL 1993c, and DOE-RL 1993d]) which are considered representative of the source areas in the 100 Area. Detailed discussion of the site groups and development of the associated group profiles are documented in Section 3.0 of this Process Document.

2) <u>Develop Remedial Alternatives</u>

Develop remedial alternatives based on the group profiles. Identify additional alternative components or *enhancements* which may be incorporated into the alternatives on a case-by-case basis in order to maximize the number of sites within each group for which the alternatives will be applicable. For each alternative, identify site characteristics or *applicability criteria* that must be met in order to ascertain the applicability of the subject alternative. For example, the no interim action alternative may be applicable to a site if concentrations of all contaminants of potential concern (COPC) are less than corresponding preliminary remediation goals (PRG). Detailed description of the IRM alternatives and specification of associated applicability criteria are presented in Section 4.0 of this Process Document.

3) Perform Detailed and Comparative Analyses

Perform detailed and comparative analyses of the IRM alternatives. The detailed and comparative analyses are presented in Sections 5.0 and 6.0 (respectively) of this Process Document.

4) Develop Individual Site Profiles

Develop a site profile for each site within an operable unit. Development of individual site profiles are documented in Section 2.0 of the applicable operable unit-specific FFS.

5) Identify Representative Group

Compare the individual site profile to the group profiles presented in this Process Document to determine the waste site group to which the subject site belongs. Compare the site characteristics to the applicability criteria for the alternatives developed for the waste site group noting any deviations which may result in a requirement for alternative enhancement or site-specific re-evaluation. Identification of the appropriate site group, and comparison to the associated alternative applicability criteria for each site are documented in Section 3.0 of the applicable operable unit-specific FFS.

6) "Plug-In" or Perform Site-Specific Analysis

a. If applicability criteria are met based on the comparison conducted in step 5, the waste site plugs into the analysis of the alternative for the group. Site-specific volume and cost estimates are documented in Section 5.0 of the operable unit-specific reports.

b. If applicability criteria are not met, the site does not plug into the analysis of the alternative for the group. Deviations from the developed group alternative will be documented in Section 4.0 of the operable unit-specific FFS. A re-evaluation of the alternative based on site-specific conditions is then performed and documented in Sections 5.0 and 6.0 of the operable unit-specific FFS.

The plug-in approach carries many benefits. First, the generation of many redundant FFS for source sites within the 100 Area is precluded. Considering the number of individual 100 Area source sites, this is expected to save a significant amount of time and resources.

Second, it focuses ongoing or subsequent data collection efforts at a site on the most likely IRM alternative(s); pursuit of superfluous data is eliminated.

Third, the plug-in approach represents a logical extension of the "analogous site" approach to site characterization discussed in the HPPS. Specifically, the HPPS (DOE-RL 1991) states:

> "Within and among many of the operable units, there are areas that are geologically similar and that have experienced similar disposal activities. Significant savings in time, manpower and budget could be realized by using these analogous conditions and activities to reduce the amount of investigation required at the affected sites. ... ... adequate confirmatory investigations would be performed in lieu of full characterization efforts."

Thus, the 100 Area source operable unit FFS employs the plug-in approach by evaluating remedial alternatives for waste site groups based on the premise that the analysis of alternatives for a group can be applied to individual waste sites in subsequent operable unit-specific FFS.

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Figure 1-1 Hanford Site Map

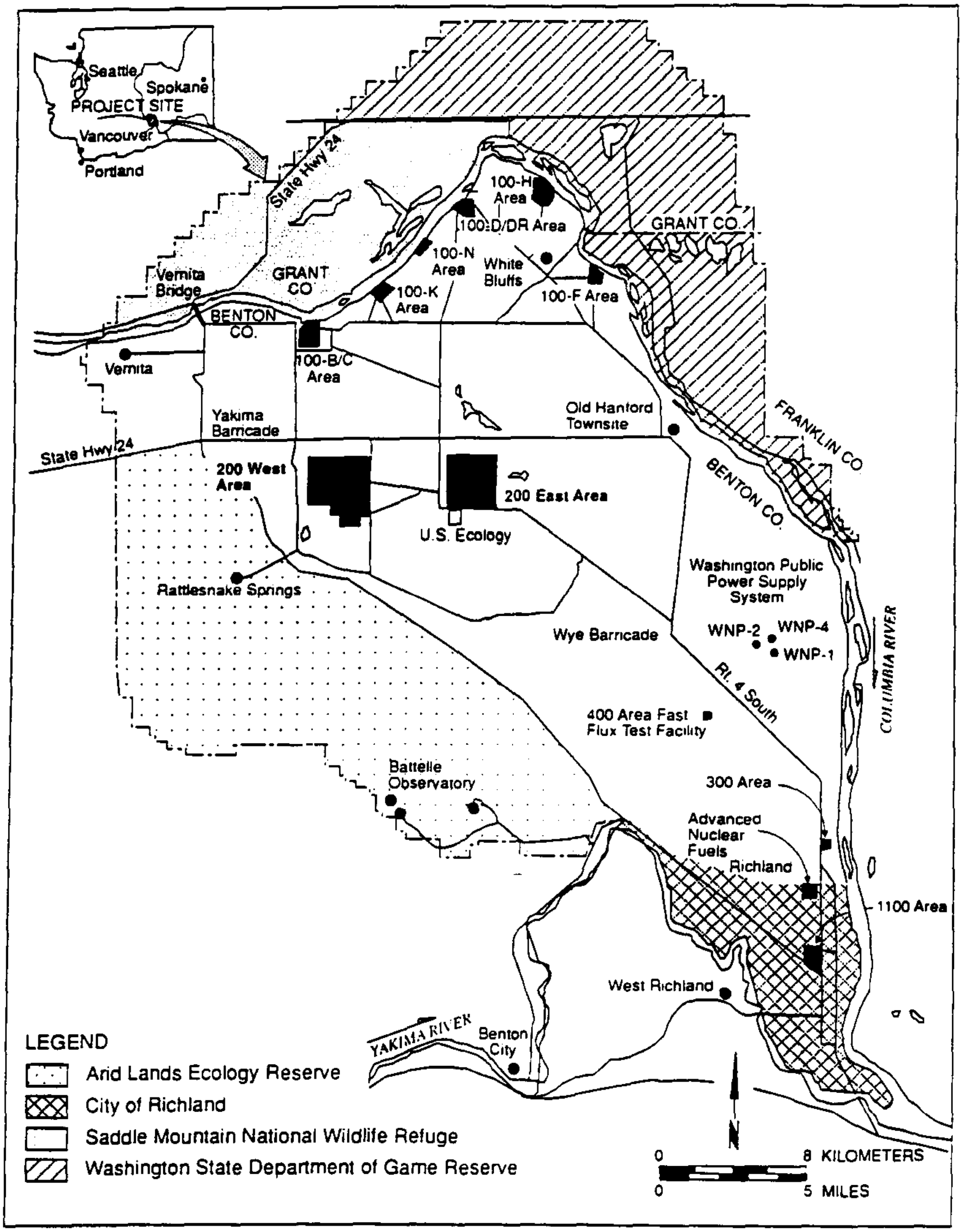

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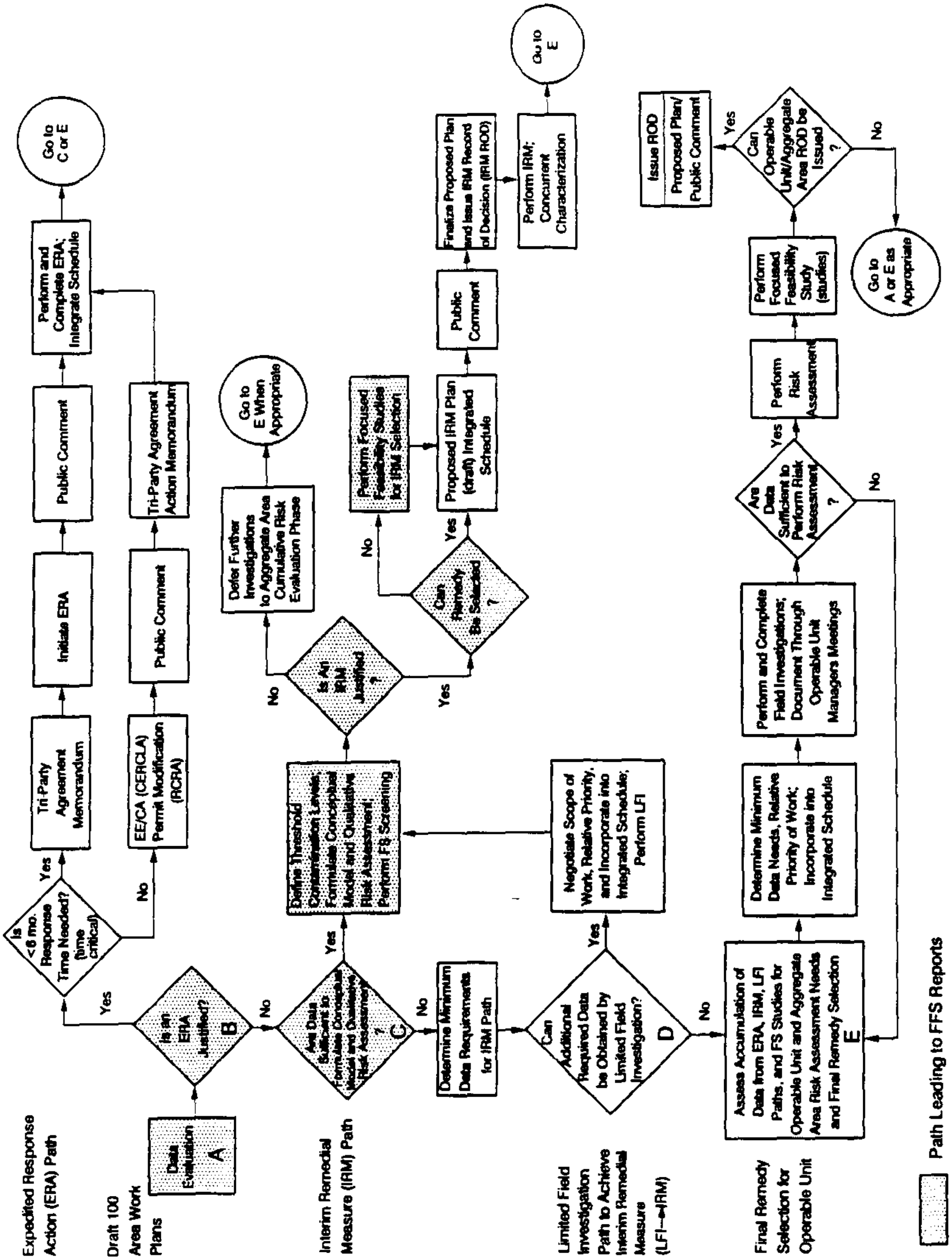
Figure 1-2 Hanford Past-Practice Strategy



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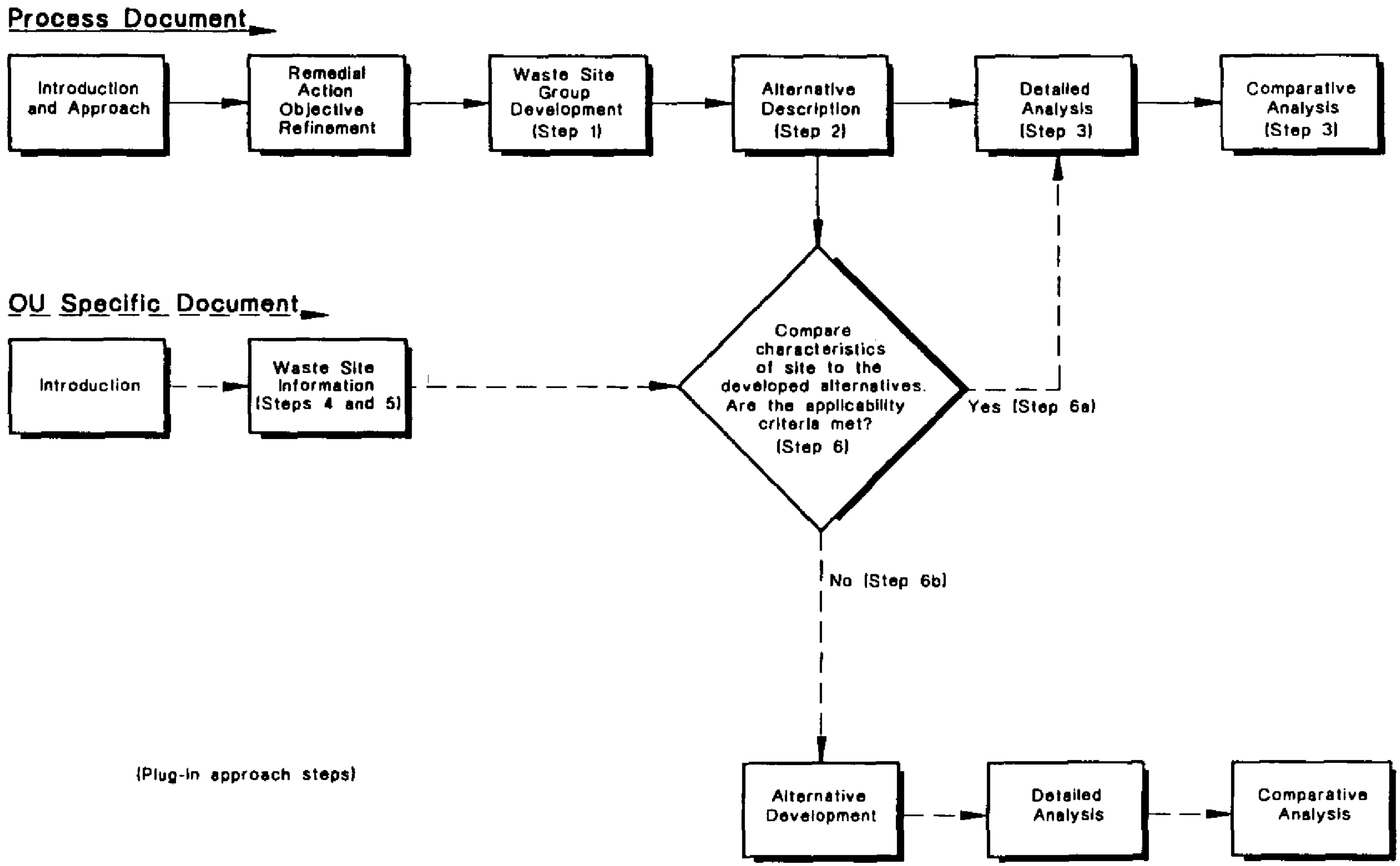

Figure 1-3 100 Area Source Operable Unit FFS Process

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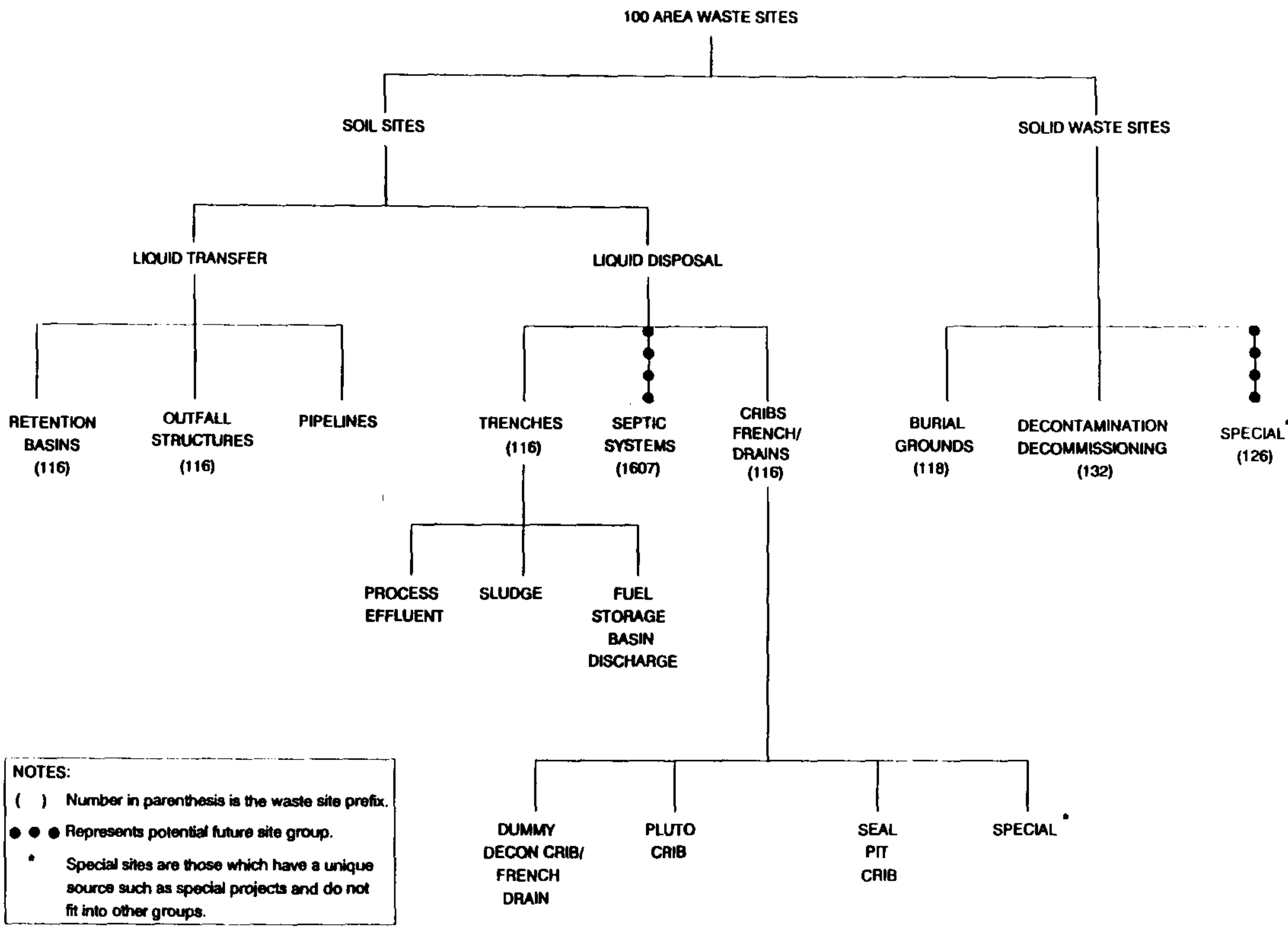

Figure 1-4 Analogous Waste Sites

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2.0 REMEDIAL ACTION OBJECTIVE REFINEMENT

Remedial action objectives are media-specific or operable unit-specific objectives for protecting human health and the environment. The RAO specify the COPC for the media of interest, exposure pathways, and acceptable contaminant levels such that an appropriate range of waste management options can be developed for analysis. This section presents the steps taken in refining the initial RAO developed in the FS Phases 1 and 2 (DOE-RL 1993a).

Remedial action objectives specified for protecting human receptors express both constituent concentrations and an exposure route because protection can be achieved by either reducing concentrations or by eliminating the exposure pathway. Remedial action objectives for protecting the environment are expressed in terms of the receptors, media of interest, and target cleanup levels. This is because the intent of the remedial action is to preserve or restore the environmental resources.

The RAO refinement process begins with the determination of COPC for each of the source operable unit waste site groups identified in Section 1.4. Initial determination of COPC is documented in applicable LFI and qualitative risk assessments (QRA). Preliminary remediation goals for the COPC are then developed (see Appendix A) based on evaluation of ARAR, and information presented in the QRA regarding potential receptors, exposure pathways associated with the proposed land use scenario, and applicable points of compliance.

The PRG for 100 Area soils incorporate values which are protective of groundwater quality since contamination at any depth in the vadose zone has the potential to impact groundwater. The protection of groundwater valves are very conservative due to the uncertainty associated with the limited data available on extent of contamination as well as with input parameters for the model used. It should be noted, however, that the PRG developed and used in this FFS do not constitute clean up criteria. The PRG are a tool used to identify refined COPC, estimate extent of contamination, and aid in the performance of volume and cost estimates. The clean-up criteria for the 100 Areas have not been developed at this time, however, decision makers will need to develop them prior to issuance of the ROD.

The concentrations of each COPC are then compared to the PRG. If the observed concentrations exceed one or more of the established PRG, the COPC is designated a refined COPC. The list of the refined COPC and associated PRG developed for each waste site group form the basis of the subsequent definition and evaluation of IRM alternatives.

The initial list of COPC is provided in Section 2.1. Applicable or relevant and appropriate requirements, proposed land use, receptors, exposure pathways, and points of compliance for the 100 Area source operable units are summarized in Sections 2.2 through 2.4. Remedial action objectives for the 100 Area source operable units are summarized in Section 2.5. Finally, refined COPC for each waste site group are introduced in Section 2.6. Additional information relevant to the specification of RAO, including detailed presentation of the PRG development process, is provided in Appendix A. Short term risks to human and ecological receptors from the interim actions are presented in Section 5.1.

2.1 CONTAMINANTS OF POTENTIAL CONCERN

The identification of COPC is required to facilitate the identification of ARAR, exposure pathways, and PRG. The COPC for this FFS represent a cumulative list of the COPC identified in the LFI and QRA reports from representative 100 Area source operable units (100-BC-1, 100-HR-1, and 100-DR-1) (DOE-RL 1993c, WHC 1994a, DOE-RL 1993d, WHC 1994b, DOE-RL 1993b, WHC 1994c). The COPC are specifically those consistent which passed the screening performed in the QRA. The constituents identified by the QRA as being COPC exceeded one or more of the following criteria:

- exceedance of Hanford Site Background (95% upper threshold limit for inorganics)

- exceedance of preliminary risk-based screening using a 1 x 10^{-7} residential exposure level and a hazard quotient (HQ) of 0.1.

The above criteria are based on human health exposures. To account for COPC identified for ecological receptors, those constituents which were used in the QRA to estimate dose to the Great Basin pocket mouse are included in the source operable unit FFS as COPC. Even though the QRA used a 15 ft cutoff for the evaluation of risks, the source operable unit FFS considers contaminants at all depths.

The COPC are identified in Table 2-1.

2.2 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Remedial actions shall strive to comply with ARAR as part of assuring protectiveness of human health and the environment. An ARAR is a promulgated Federal or State cleanup standard, standard of control, substantive environmental protection requirement, applicability criteria, or limitation. It must be either/or:

- "applicable," specifically addresses the substances, location or action being considered

- "relevant and appropriate," addresses a situation sufficiently similar to that encountered at the CERCLA site such that its use is well suited to the particular site. A standard or criterion must be both relevant and appropriate to be an ARAR.

There are three categories of ARAR:

- Chemical-specific ARAR - numerical values or methodologies used to determine acceptable concentrations of a contaminant.

- Location-specific ARAR - requirements that dictate or restrict actions at or surrounding the CERCLA site because of sensitive or unique conditions present at that location.

- Action-specific ARAR - technology or activity-based requirements or limitations on actions taken with respect to hazardous waste.

In addition to ARAR, remedial actions are evaluated with respect to "to-be-considered" (TBC) requirements. A TBC is a nonpromulgated criterion, advisory, guideline, or proposed regulation. Because TBC are not legally binding, they do not have the status of ARAR; however, TBC are identified and considered because ARAR may not exist for the substances or situations of concern, or the ARAR alone would not be sufficiently protective.

Chemical-specific ARAR and TBC used in the analysis of alternatives for the source operable unit FFS are identified in Table 2-2 through 2-4; location-specific in Table 2-5 through 2-7; and action-specific in Table 2-8 through 2-10.

2.3 LAND USE

The *Hanford Future Site Uses Working Group* (DOE-RL 1992a) has recommended that the 100 Areas be considered for the following four future use options:

- Native American uses
- limited recreation, recreation-related commercial uses and wildlife uses
- B Reactor as a museum/visitor center
- wildlife and recreation uses.

Furthermore, the Final River Conservation Study and EIS for the Hanford Reach of the Columbia River (National Park Service 1993) has proposed that the Hanford Reach of the Columbia River and approximately 102,000 acres of adjacent lands be designated as a National Wild and Scenic River, and a National Wildlife Refuge, respectively.

All the above proposed future use options are compatible with a recreational land use scenario. Accordingly, receptors, exposure pathways and points of compliance will be specified in accordance with a recreational exposure scenario defined by the *Hanford Site Baseline Risk Assessment Methodology* (DOE-RL 1993e).

2.4 RECEPTORS, EXPOSURE PATHWAYS, AND POINTS OF COMPLIANCE

Since RAO can be met by mitigating exposure pathways, definition of exposure pathways specific to each of the receptors is necessary. The comprehensive conceptual exposure pathway model is presented in Figure A-1 (Appendix A) and is based on a recreational exposure scenario. The receptors are:

- human site visitors and site workers
- terrestrial biota.

Refinement of the conceptual model involves identifying receptors and points of compliance for the exposure pathways of concern.

2.4.1 Receptors

The human site visitor and site worker are defined in Figure A-1 as long-term and short-term receptors, respectively. A qualitative evaluation of short term risk to human and ecological receptors due to the interim actions is presented in Section 5.1. The terrestrial biota identified in Figure A-1 encompass all biota that can enter the site. However, two taxa, an animal and a plant, are selected as representative of terrestrial biota in the 100 Areas: these are the Great Basin pocket mouse and a generic plant.

Humans and the Great Basin pocket mouse were evaluated in the QRA. Potential hazards to terrestrial plants were not, however, assessed in the QRA. Exposure pathways used in the development of human health PRG are consistent with that used in the QRA evaluation. Because no published method exists for the derivation of ecological PRG, numerical PRG were not estimated for pocket mice or plants. When applicable, PRG protective of human health were adopted in place of species-specific ecological PRG in the zones accessible by ecological receptors. Impact to groundwater was qualitatively evaluated in the QRA and LFI. The PRG development also incorporated a more quantitative assessment of potential impact to groundwater by calculation of soil concentrations which are protective of the groundwater resource (see Appendix A).

2.4.2 Exposure Pathways

The exposure pathways of concern for the human receptor include external exposure to radiation, ingestion and inhalation. Plant receptors are impacted through uptake of contamination from the soil into the plant biomass. Animal receptors (pocket mouse) are impacted by ingestion of plants.

2.4.3 Points of Compliance

Points of compliance are discrete points where a given cleanup level must be achieved. The points may be different for varying receptors. The PRG is dependent upon if the area is accessible by humans, plants, wildlife, and other media such as groundwater. It is at the interface of the different zones of receptor accessibility that the points of compliance are defined. The QRA identified depths to which receptors are impacted by contaminants. Humans are susceptible to external exposure to radiation in the first meter of soil (WHC 1994c). Wildlife, specifically mammals, may burrow in the first 2 m of soil (WHC 1994b). Plant roots may penetrate to depths of 2 to 3 m (Klepper et al. 1985). Groundwater is impacted by any leachable contaminants in the vadose zone, therefore levels protective of the groundwater resource should be met throughout the soil column. Figure A-2 graphically displays the zones of receptor accessibility.

2.5 REMEDIAL ACTION OBJECTIVES

The RAO are specific applicability criteria that the remediation will fulfill. The COPC developed in Section 2.1 are used to define the RAO. These objectives can be numerically expressed as PRG. The PRG establish initial concentrations that are considered protective of human health and the environment for the defined land use. The PRG are necessary to establish preliminary extents of contamination which are required to perform volume and cost estimates. Appendix A discusses the development of the PRG. The RAO are defined below:

- For Human Health
  - Limit exposure of human receptors to contaminated surface and subsurface soils in order to maintain receptor risk in the range of 10^{-04} to 10^{-06} for carcinogenic constituents and at or below the PRG for noncarcinogen constituents. This will be accomplished by eliminating exposure pathways or reducing contaminant concentrations.
  - Limit future impacts to groundwater by ensuring that contamination which may remain in the vadose zone will be at or below levels considered protective of groundwater.
  - Strive to comply with ARAR to the extent practicable.

- For Environmental Protection:
  - Limit exposure of ecological receptors to contaminants by minimizing contaminant concentration or accessibility.
  - Strive to comply with ARAR to the extent practicable.

Final remediation goals will be determined by the signatories to the Tri-Party Agreement when the remedy is selected and will be documented in the ROD.

2.6 GROUP-SPECIFIC REFINED CONTAMINANTS OF POTENTIAL CONCERN

In the context of this FFS, refined COPC are those constituents which must be addressed by remedial actions. To create the list of refined COPC, the historical and LFI data from the representative operable units (100-BC-1, 100-D-1, 100-HR-1) are reviewed to identify contaminant concentrations for the COPC defined in Section 2.1. The data for each COPC are then screened against the PRG. Those constituents which exceed the PRG are considered the refined COPC for each waste site. Refined COPC for a group are those constituents which exceed PRG in the majority (at least half) of the sites where data was collected. The refined COPC for each group are presented in the waste site group profiles in Section 3.0.

Table 2-1 Contaminants of Potential Concern

Radionuclides	Inorganics	Organics
Tritium	Antimony	Aroclor 1260 (PCB)
Carbon-14	Arsenic	Benzo(a)pyrene
Sodium-22	Barium	Chrysene
Potassium-40	Cadmium	Pentachlorophenol
Cobalt-60	Chromium VI	
Nickel-63	Lead	
Strontium-90	Manganese	
Technetium-99	Mercury	
Cesium-134	Zinc	
Cesium-137		
Europium-152		
Europium-154		
Europium-155		
Radium-226		
Thorium-228		
Thorium-232		
Uranium-233/234		
Uranium-235		
Plutonium-238		
Uranium-238		
Plutonium-239/240		
Americium-241		

PCB - polychlorinated biphenyl

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Table 2-2 Potential Federal Chemical-Specific ARAR (page 1 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Atomic Energy Act of 1954, as amended	42 U.S.C. 2011 et seq.		Authorizes DOE to set standards and restrictions governing facilities used for research, development, and utilization of atomic energy.		
Radiation Protection Standards	40 CFR Part 191		Establishes standards for management and disposal of high-level and transuranic waste and spent nuclear fuel.		
Standards for Management and Storage	40 CFR §191.03	A	Requires that management and storage of spent nuclear fuel or high-level or transuranic (TRU) radioactive wastes at all facilities for the disposal of such fuel or waste that are operated by the DOE and that are not regulated by the Commission or Agreement States shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public in the general environment resulting from discharges of radioactive material and direct radiation from such management and storage shall not exceed 25 millirems to the whole body and 75 millirems to any critical organ.	Applicable to wastes disposed of after November 18, 1985.	SW-4, SW-9, SS-4, SS-10
Nuclear Regulatory Commission Standards for Protection Against Radiation	10 CFR Part 20				
Occupational Dose Limits	10 CFR Part 20 Subpart C	R&A	Sets occupational dose limits for adults. Total effective dose equivalent equal to 5 rem/year.		ALL
Radiation Dose Limits for Individual Members of the Public	10 CFR Part 20 Subpart D	R&A	Requires Licensed Facility to assure that the total effective dose euivalent to individual members of the public from the licensed operation does not exceed 0.1 rem/year. The dose in any unrestricted area from external sources does not exceed 0.002 rem in any one hour.		ALL

Table 2-2 Potential Federal Chemical-Specific ARAR (page 2 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Safe Drinking Water Act	42 U.S.C. 300f et seq.		Creates a comprehensive national framework to ensure the quality and safety of drinking water.		
National Primary Drinking Water Regulations	40 CFR Part 141	R&A	Establishes maximum contaminant levels (MCL) and maximum contaminant level goals (MCLG) for organic, inorganic, and radioactive constituents. The MCL for combined radium-226 and radium-228 is 5 pCi/L. The MCL for gross alpha particle activity (including radium-226 but excluding radon and uranium) is 15 pCi/L. The average annual concentration of beta particle and photon radioactivity from manmade radionuclides in drinking water shall not produce an annual dose equivalent to total body or any internal organ in excess of 4 millirem/year.	Applicable to public water systems. Potential chemicals and radionuclides of concern may migrate to the drinking water supply as a result of remedial activities. Although federal MCLGs are not enforceable standards, they are potential ARARs under the Washington State Model Toxics Control Act when more stringent than other standards. See state ARARs.	All
			μg/l		
			fluoride 4000		
			barium 2000		
			cadmium 5		
			chromium 100		
			mercury 2		
			nitrate 10,000		
			nitrite 1000		
			antimony 6		
			beryllium 4		
			cyanide 200		
			nickel 100		
			PCB .5		
			pentachlorophenol 1.0		
			Benzo(a)pyrene .2		

Table 2-2 Potential Federal Chemical-Specific ARAR (page 3 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
National Secondary Drinking Water Regulations	40 CFR Part 143	R&A	Controls contaminants in drinking water that primarily affect the aesthetic qualities relating to the public acceptance of drinking water. µg/l chloride 250,000 copper 1000 iron 300 foaming agents 500 manganese 50 sulfate 250,000 TDS 500,000 zinc 5000 aluminum 50-200 color 15 color units odor 3 threshold odor units pH 6.5-8.5	Although federal secondary drinking water standards are not enforceable, they are potential ARARs under the Washington State Model Toxics Control Act when more stringent than other standards. See state ARARs.	All

Table 2-2 Potential Federal Chemical-Specific ARAR (page 4 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act (RCRA)	42 U.S.C. 6901 et seq.		Establishes the basic framework for federal regulation of solid and hazardous waste.		
Groundwater Protection Standards	40 CFR §264.92-99 [WAC 173-303-6 45][1]	A	A facility shall not contaminate the uppermost aquifer underlying the waste management area beyond the point of compliance, which is a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated area. The concentration of certain chemicals shall not exceed background levels, certain specified maximum concentrations, or alternate concentration limits, whichever is higher. μg/l arsenic 50 barium 1000 cadmium 10 chromium 50 lead 50 mercury 2 silver 50	Groundwater concentration limits in this section do not exceed 40 CFR 141, except for chromium which has a limit of 100 μg/L.	All
Uranium Mill Tailings Radiation Control Act of 1978	Public Law 95-604, as amended				
Standards for Uranium and Thorium Mill Tailings	40 CFR 192		Establishes standards for control, cleanup, and management of radioactive materials from inactive uranium processing sites.		

[1]These are State of Washington regulatory citations which are equivalent to Title 40 Code of Federal Regulations, Parts 264 and 268 as stated in Washington Administrative Code 173-303.

Table 2-2 Potential Federal Chemical-Specific ARAR (page 5 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Land Cleanup Standards	40 CFR §§192.10 - 192.12	R&A	Requires remedial actions to provide reasonable assurance that, as a result of residual radioactive materials from any designated processing site, the concentration of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than 5 pCi/g, averaged over the first 15 cm of soil below the surface, and 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface. In any habitable building, a reasonable effort shall be made during remediation to achieve an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 Working Level (WL). In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL and the level of gamma radiation shall not exceed the background level by more than 20 microroentegens per hour.	May be relevant and appropriate, as any radium-226 encountered during remediation did not result from uranium processing.	All
Implementation	40 CFR §§192.20 - 192.23	R&A	Requires that when radionuclides other than radium-226 and its decay products are present in sufficient quantity and concentration to constitute a significant radiation hazard from residual radioactive materials, remedial action shall reduce other residual radioactivity to levels as low as reasonably achievable (ALARA).	May be relevant and appropriate, as any radium-226 encountered during remediation did not result from uranium processing.	All

*NOTE: A = Applicable, R&A = Relevant and Appropriate

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Table 2-3 Potential State Chemical-Specific ARAR (page 1 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Department of Social and Health Services (Drinking Water)	43.20A RCW				
Public Water Supplies	WAC 248-54		Establishes requirements to protect users of public drinking water supplies.		
Maximum Contaminant Levels (MCL)	WAC 248-54-175	A	The MCL for radium-226 is 3 pCi/L.	The level for radium-226 exceeds the federal MCL in 40 CFR 192.	All
Model Toxics Control Act (MTCA)	70.105D RCW		Requires remedial actions to attain a degree of cleanup protective of human health and the environment.		
Cleanup Regulations	WAC 173-340		Establishes cleanup levels and prescribes methods to calculate cleanup levels for soils, groundwater, surface water, and air.		

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Table 2-3 Potential State Chemical-Specific ARAR (page 2 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Groundwater Cleanup Standards	WAC 173-340-720	A	Requires that where the groundwater is a potential source of drinking water, cleanup levels under Method B must be at least as stringent as concentrations established under applicable state and federal laws, including the following: (A) MCL established under the Safe Drinking Water Act and published in 40 CFR 141, as amended; (B) MCLG for noncarcinogens established under the Safe Drinking Water Act and published in 40 CFR 141, as amended; (C) Secondary MCL established under the Safe Drinking Water Act and published in 40 CFR 143, as amended; and (D) MCL established by the state board of health and published in Chapter 248-54 WAC, as amended.	Federal MCLG for drinking water (40 CFR Part 141) and federal secondary drinking water regulation standards (40 CFR Part 143) are potential ARARs under MTCA when they are more stringent than other standards. Method B cleanup levels are levels applicable to remediation at Hanford unless a demonstration can be made that method C (alternate cleanup levels) is valid. Method B (July 1993 update tables) — μg/l antimony 6.4 arsenic .05 barium 1120 benzo(a)pyrene .012 beryllium .0203 cadmium 8 chromium VI 80 chrysene .012 copper 592 cyanide 320 fluoride 960 manganese 80 mercury 4.8 nickel 320 nitrite 1600 pentachlorophenol .729 pyrene 480 silver 48 zinc 4800	All

Table 2-3 Potential State Chemical-Specific ARAR (page 3 of 5)

Description	Citation	A/ R&A*	Requirements		Remarks	Alternatives Potentially Affected
Soil Cleanup Standards	WAC 173-340-740	R&A	MTCA Method B (July 1993 update tables) concentration limits in milligrams per kilogram for potential contaminants in soils, sediments, and sludges are:			All
			Antimony	32.0		
			Manganese	400.0		
			PCBs	0.13		
			Arsenic	1.43		
			Barium	5600.0		
			Benzo(a)pyrene	1.37		
			Cadmium	40.0		
			Chromium VI	400.0		
			Chrysene	0.137		
			Copper	2960.0		
			Mercury	24.0		
			Nickel	1600.0		
			Nitrite	8000.0		
			Pentchlorophenol	8.33		
			Pyrene	2400.0		
			Silver	240.0		
			Zinc	24000.0		

Table 2-3 Potential State Chemical-Specific ARAR (page 4 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Water Pollution Control	90.48 RCW				
Surface Water Quality Standards	WAC 173-201		Sets surface water quality standards for the state.		
Water Criteria Classes	WAC 173-201-045	A	Standards for surface water designated "Class A" include: freshwater temperature shall not exceed 18.0°C due to human activities. Temperature increases shall not at any time exceed t = 28/T+7 where "t" represents the maximum permissible temperature increase measured at a dilution zone boundary and "T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge. When natural conditions exceed 18.0° (freshwater) and 16.0° (marine water), no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C. Provided that temperature increase resulting from nonpoint source activities shall not exceed 2.8°C, and the maximum water temperature shall not exceed 18.3°C (freshwater). pH shall be within the range of 6.5 to 8.5 (freshwater) with a man-caused variation within a range of less than 0.5 units.	The Hanford reach of the Columbia River is classified "Class A."	SS-10, SW-4, SW-7, SW-8, SW-9, SS-4

Table 2-3 Potential State Chemical-Specific ARAR (page 5 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Toxic Substances	WAC 173-201-047	A	Sets surface water limits for toxic substances. Freshwater limits in micrograms per liter for 100 Area contaminants are: Cadmium (acute): $\leq e^{(1.128[\ln(\text{hardness})]-3.828)}$ [a] Cadmium (chronic): $\leq e^{(0.7852[\ln(\text{hardness})]-3.490)}$ [b] Lead (acute): $\leq e^{(1.273[\ln(\text{hardness})]-1.460)}$ [a] Lead (chronic): $\leq e^{(1.273[\ln(\text{hardness})]-4.705)}$ [b] Nickel (acute): $\leq e^{(0.8460[\ln(\text{hardness})]+3.3612)}$ [a] Nickel (chronic): $\leq e^{(0.8460[\ln(\text{hardness})]+1.1645)}$ [b] (acute) (chronic) Chlorine 19.0[a] 11.0[b] Chromium 16.0[a] 11.0[b] Cyanide 22.0[a] 5.2[b] Mercury 2.4[a] 0.012[b] PCBs 2.0[c] 0.014[c] [a]A one-hour average concentration not to be exceeded more than once every three years. [b]A four-day average concentration not to be exceeded more than once every three years. [c]A 24-hour average not to be exceeded. NOTE: Hardness is a measure of the calcium and magnesium salts present in water, measured in milligrams per liter as calcium carbonate.		All
Radiation Protection -- Air Emissions	WAC 246-247		Estabilishes procedures for monitoring, control, and reporting of airborne radionuclide emissions.		
New and Modified Sources	WAC 246-247-070	A	Requires the use of best available radionuclide control technology (BARCT),		All
Radiation Protection Standards	WAC 246-221		Establishes standards for protection against radiation hazards.		
Radiation dose to individuals in restricted areas	WAC 246-221-010	A	Specifies dose limits to individuals in restricted areas for hands and wrists, ankles and feet of 18.75 rem/quarter and for skin of 7.5 rem/quarter.		All

*NOTE: A = Applicable, R&A = Relevant and Appropriate

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Table 2-4 Potential Chemical-Specific TBC (page 1 of 4)

Description	Citation	Requirements	Remarks	Alternatives Potentially Affected
Benton-Franklin-Walla Walla Counties Air Pollution Control Authority	General Regulation 80-7			
Maximum Permissible Emissions	Section 400-040	Prohibits emission of air contaminants for more than 3 minutes/hour when emissions at or near the emission source exceed 20 percent opacity, except under special circumstances.		SW-3, SW-4, SW-7, SW-9, SS-3, SS-4, SS-8, SS-10
Maximum Allowable Emissions for Combustion and Incineration Sources	Section 400-050	Prohibits emissions exceeding 100 ppm of total carbonyls.		SW-9, SS-8, SS-10
Maximum Emissions for General Process Sources	Section 400-060	Prohibits emissions of particulates from general process sources exceeding 0.10 grain (.0065 gram) per standard cubic foot of dry exhaust gas.	Pertinent to sources that result in a physical or chemical change in material (excluding combustion).	SW-9, SS-8, SS-10, SW-7
City of Richland	Ordinance No. 35-84	Prohibits discharges which may interfer with the city's water treatment facility. Also prohibits discharges of toxic pollutants in sufficient quantity to constitute a hazard to humans or animals. Establishes limits for pH, temperature, and chemical constituents.		All
A Guide on Remedial Actions at Superfund Sites with PCB Contamination	EPA Directive 9355-.4-01FS	Provides a general framework for determining cleanup levels, identifying treatment options, and assessing necessary management controls for residuals.		All
Safe Drinking Water Act	42 U.S.C. 300f et seq.			
National Primary Drinking Water Regulations	40 CFR 141	Proposed maximum contaminant level goals (MCLGs) (Federal Register, July 18, 1991) are: <u>Contaminant</u> — <u>MCLG</u> Radium-226 — zero Radium-228 — zero Uranium — zero Gross alpha emitters — zero Beta and photon emitters — zero	Federal MCLGs are ARAR under MTCA when they are more stringent than other state standards.	All

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Table 2-4 Potential Chemical-Specific TBC (page 2 of 4)

Description	Citation	Requirements	Remarks	Alternatives Potentially Affected
National Primary Drinking Water Regulations; Radionuclides - Proposed Rules	FR Vol. 56, No. 138, July 18, 1991	Provides numerical standards for radionuclides corresponding to 4 mrem/yr dose through drinking water as follows (pCi/L): Tritium 60,900 Carbon-14 3,200 Cobalt-60 218 Nickel-63 9,910 Strontium-90 42 Technitium-99 3,790 Cesium-134 81.3 Cesium-137 119 Europium-152 841 Europium-154 573 Europium-155 3590 Radium-226 15.7 Radium-228 7.85 Uranium-233 13.8 Uranium-234 13.9 Uranium-235 14.5 Uranium-238 14.6 Plutonium-238 7.02 Plutonium-239 62.1 Plutonium-240 62.2 Americium-241 6.34	When promulgated, these proposed rules will replace sections in 40 CFR 141 and 142	All
U.S. Department of Energy Orders				
Radiation Protection of the Public and the Environment	DOE 5400.5	Establishes radiation protection standards for the public and environment.		
Radiation Dose Limit (All Pathways)	DOE 5400.5, Chapter II, Section 1a	The exposure of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an effective dose equivalent greater than 100 mrem from all exposure pathways, except under specified circumstances.	Pertinent if remedial activities are "routine DOE activities."	All

Table 2-4 Potential Chemical-Specific TBC (page 3 of 4)

Description	Citation	Requirements	Remarks	Alternatives Potentially Affected
Radiation Dose Limit (Drinking Water Pathway)	DOE 5400.5, Chapter II, Section 1d	Provides a level of protection for persons consuming water from a public drinking water supply operated by DOE so that persons consuming water from the supply shall not receive an effective dose equivalent greater than 4 mrem per year. Combined radium-226 and radium-228 shall not exceed 5 x 10^{-9} μCi/mL and gross alpha activity (including radium-226 but excluding radon and uranium) shall not exceed 1.5 x 10^{-8} μCi/mL.	Pertinent if radionuclides may be released during remediation.	All
Residual Radionuclides in Soil	DOE 5400.5 Chapter IV, Section 4a	Generic guidelines for radium-226 and radium-228 are: • 5 pCi/g averaged over the first 15 cm of soil below the surface; and • 15 pCi/g averaged over 15-cm-thick layers of soil more than 15 cm below the surface. Guidelines for residual concentrations of other radionuclides must be derived from the basic dose limits by means of an environmental pathway analysis using specific property data where available. Procedures for these deviations are given in "A Manual for Implementing Residual Radioactive Material Guidelines" (DOE/CH-8901). Procedures for determination of "hot spots," "hot-spot cleanup limits," and residual concentration guidelines for mixtures are in DOE/CH-8901. Residual radioactive materials above the guidelines must be controlled to the required levels in 5400.5, Chapter II and Chapter IV.	Residual concentrations of radioactive material in soil are defined as those in excess of background concentrations averaged over an area of 100 m^2.	All
Issues Paper on Radiation Site Cleanup Regulations	EPA Document 402-R-93-084	The U.S. Environmental Protection Agency (EPA) is developing regulations that will set forth requirements for cleanup levels for sites contaminated with radionuclides. This is an Issues Paper to present issues, alternative regulatory approaches, and preliminary analyses that are relevant to the development of radiation site cleanup regulations.	Approaches discussed for cleanup regulations include: • cleanup to instrument detection limits • cleanup to background, or natural, radiation levels • cleanup to risk based level or range considered protective of human health and the environment. • cleanup levels based on the performance of the Best Demonstrated Available Technology (BDAT)	All

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Table 2-4 Potential Chemical-Specific TBC (page 4 of 4)

Description	Citation	Requirements	Remarks	Alternatives Potentially Affected
NRC Draft Radiological Criteria for Decommissioning	10 CFR Part 20 (proposed revision)	The intent of this rulemaking is to provide a clear and consistent regulatory basis for determining the extent to which lands and structures must be remediated before a site can be considered decommissioned. The primary goal is to return the site to levels approximately background. Indistinguishable from background is defined as no more that 3 mrem per year over background. The limit would be 15 mrem/year over background with the goal to be as close to 3 mrem/year over background as is reasonably achievable.		All

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Table 2-5 Potential Federal Locations-Specific ARAR (page 1 of 2)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Archaeological and Historical Preservation Act of 1974	16 U.S.C. 469	A	Requires action to recover and preserve artifacts in areas where activity may cause irreparable harm, loss, or destruction of significant artifacts.	Applicable when remedial action threatens significant scientific, prehistorical, historical, or archeological data.	SW-2, SW-3, SW-4, SW-7, SW-9, SS-2, SS-3, SS-4, SS-8, SS-10
Endangered Species Act of 1973	16 U.S.C. 1531 et seq.		Prohibits federal agencies from jeopardizing threatened or endangered species or adversely modifying habitats essential to their survival.		
Fish and Wildlife Services List of Endangered and Threatened Wildlife and Plants	50 CFR Parts 17, 222, 225, 226, 227, 402, 424	A	Requires identification of activities that may affect listed species. Actions must not threaten the continued existence of a listed species or destroy critical habitat.	Requires consultation with the Fish and Wildlife Service to determine if threatened or endangered species could be impacted by activity.	All
Historic Sites, Buildings, and Antiquities Act	16 U.S.C. 461	A	Establishes requirements for preservation of historic sites, buildings, or objects of national significance. Undesirable impacts to such resources must be mitigated.		SW-1, SW-2, SW-3, SW-4, SW-7, SW-9, SS-1, SS-2, SS-3, SS-4, SS-8, SS-10
National Historic Preservation Act of 1966, as amended.	16 U.S.C. 470 et seq.	A	Prohibits impacts on cultural resources. Where impacts are unavoidable, requires impact mitigation through design and data recovery.	Applicable to properties listed in the National Register of Historic Places, or eligible for such listing.	SW-2, SW-3, SW-4, SW-7, SW-9, SS-2, SS-3, SS-4, SS-8, SS-10
Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act (RCRA)	42 U.S.C. 6901 et seq.		Establishes the basic framework for federal regulation of solid and hazardous waste.		
Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257		Sets criteria for determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health or the environment.		

Table 2-5 Potential Federal Locations-Specific ARAR (page 2 of 2)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Floodplains	40 CFR §257.3-1	A	Prohibits facilities or practices in floodplains from restricting the flow of the base flood, reducing the temporary water storage capacity of the floodplain, or causing washout of solid waste, so as to pose a hazard to human life, wildlife, or land or water resources.		SW-3, SW-4, SW-7, SW-9, SS-3, SS-4, SS-8, SS-10
Endangered Species	40 CFR §257.3-2	A	Prohibits facilities or practices from causing or contributing to the taking of any endangered or threatened species of plants, fish, or wildlife. Prohibits destruction or adverse modification of habitat of endangered or threatened species.		All
Hazardous Waste Treatment, Storage, and Disposal	40 CFR Part 264		Establishes standards for management of hazardous waste.	Applicable to owners and operators of all hazardous waste facilities.	
Location Standards	40 CFR §264.18	A	Prohibits new TSD facilities from being located within 61 meters (200 feet) of a fault displaced during the Holocene. Requires a facility located in a 100-year floodplain to be designed, constructed, operated, and maintained to prevent washout or release of any hazardous waste by a 100-year flood.		SW-9, SS-8, SS-10
Wild and Scenic Rivers Act	16 U.S.C 1271	A	Prohibits federal agencies from recommending authorization of any water resource project that would have a direct and adverse effect on the values for which a river was designated as a wild and scenic river or included as a study area.	The Hanford Reach of the Columbia River is under study for inclusion as a wild and scenic river.	SW-3, SW-4, SW-7, SW-9, SS-3, SS-4, SS-8, SS-10

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 2-6 Potential State Location-Specific ARAR

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Habitat Buffer Zone for Bald Eagle Rules	RCW 77.12.655				
Bald Eagle Protection Rules	WAC 232-12-292	A	Prescribes action to protect bald eagle habitat, such as nesting or roost sites, through the development of a site management plan.	Applicable if the areas of remedial activities includes bald eagle habitat.	All
Regulating the Taking or Possessing of Game	RCW 77.12.040				
Endangered, Threatened, or Sensitive Wildlife Species Classification	WAC 232-12-297	A	Prescribes action to protect wildlife classified as endangered, threatened, or sensitive, through development of a site management plan.	Applicable if wildlife classified as endangered, threatened, or sensitive are present in areas impacted by remedial activities.	All

*NOTE: A = Applicable, R&A = Relevant and Appropriate

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Table 2-7 Potential Location-Specific TBC

Description	Citation	Requirements	Remarks	Alternatives Potentially Affected
Floodplains/Wetlands Environmental Review	10 CFR Part 1022	Requires federal agencies to avoid, to the extent possible, adverse effects associated with the development of a floodplain or the destruction or loss of wetlands.	Pertinent if remedial activities take place in a floodplain or wetlands.	SW-2, SW-3, SW-4, SW-7, SW-9, SS-2, SS-3, SS-4, SS-8, SS-10
Protection and Enhancement of the Cultural Environment	Executive Order 11593	Provides direction to federal agencies to preserve, restore, and maintain cultural resources.	Pertains to sites, structures, and objects of historical, archeological, or architectural significance.	SW-1, SW-2, SW-3, SW-4, SW-7, SW-9, SS-1, SS-2, SS-3, SS-4, SS-8, SS-10
Hanford Reach Study Act	P.L. 100-605	Provides for a comprehensive river conservation study. Prohibits the construction of any dam, channel, or navigation project by a federal agency for 8 years after enactment. New federal and non-federal projects and activities are required, to the extent practicable, to minimize direct and adverse effects on the values for which the river is under study and to utilize existing structures.	This law was enacted November 4, 1988.	All

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Table 2-8 Potential Federal Action-Specific ARAR (page 1 of 7)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Atomic Energy Act of 1954	42 U.S.C. 2011 et seq.		Authorizes DOE to set standards and restrictions governing the design, location, and operation of facilities used for research, development, and utilization of atomic energy.		
Environmental Standards for Disposal	40 CFR Part 191 Subpart B	A	Established requirements for diposal of spent nuclear fuel, high-level, or TRU waste; specifies controls for disposal sites; requires barriers for disposal systems; sets criteria for selecting disposal sites and systems.	Applicable to waste disposed of after November 18, 1985.	SW-4, SW-9, SS-4, SS-10
Clean Air Act, as amended	42 U.S.C. 7401 et seq.		A comprehensive environmental law designed to regulate any activities that affect air quality, providing the national framework for controlling air pollution.		
National Primary and Secondary Ambient Air Quality Standards	40 CFR Part 50		Sets National Ambient Air Quality Standards for ambient pollutants which are regulated within a region.		
Standards for Sulfur Oxides (Sulfur Dioxide)	40 CFR §50.4	A	The primary ambient air quality standard for sulfur oxides measured as sulfur dioxide is 80 micrograms per cubic meter (0.03 ppm), annual arithmetic mean; 365 micrograms per cubic meter (0.14 ppm) maximum 24-hour concentration not to be exceeded more than once per year.	Applicable if remediation includes incineration of waste.	SS-8, SW-9, SS-10
Air Standards for Particulates	40 CFR §50.6	A	Prohibits average concentrations of particulate emissions in excess of 50 micrograms/m^3 annually or 150 micrograms/m^3 per 24-hour period.	A potential for particulate emissions exists during material handling or treatment, including incineration.	SW-3, SW-4, SW-7, SW-9, SS-3, SS-4, SS-8, SS-10
Air Standards for Carbon Monoxide	40 CFR §50.8	A	The national primary ambient air quality standards for carbon monoxide are: (1) 9 parts per million (10 milligrams per cubic meter) for an 8-hour average concentration not to be exceeded more than once per year and (2) 35 parts per million (40 milligrams per cubic meter) for a 1-hour average concentration not to be exceeded more than once per year.	Applicable if remediation includes incineration of waste.	SW-9, SS-8, SS-10

Table 2-8 Potential Federal Action-Specific ARAR (page 2 of 7)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Standards for Nitrogen Dioxide	40 CFR §50.11	A	The level of the national primary and secondary ambient air quality standard for nitrogen dioxide is 0.053 parts per million (100 micrograms per cubic meter), annual arithmetic mean concentration.	Applicable if remediation includes incineration.	SW-9, SS-8, SS-10
Air Standards for Lead	40 CFR §50.12	A	The national primary and secondary ambient air quality standard for lead and its compounds measured as elemental lead are 1.5 micrograms per cubic meter, maximum arithmetic mean averaged over a calendar quarter.	Applicable if particulates suspended during remedial activities are contaminated with lead, or if remediation includes incineration.	SW-4, SW-7, SW-9, SS-4, SS-8, SS-10
Standards for New Stationary Sources	40 CFR Part 60				
Incinerator Particulate Standards	40 CFR §60.52	A	Prohibits discharge of gases containing particulates exceeding 0.18 g/dry cubic meter at standard conditions corrected to 12 percent CO_2, on or after the date of the performance test.	Applicable to incinerators of more than 45 metric tons per day (50 tons per day) charging rate.	SW-9, SS-8, SS-10
National Emissions Standards for Hazardous Air Pollutants (NESHAP)	40 CFR Part 61		Establishes numerical standards for hazardous air pollutants.		
Emission Standard for Mercury	40 CFR §61.52	A	Prohibits emissions of mercury from sludge incineration plants or sludge drying plants exceeding 3200 grams/day.	Applicable to drying of wastewater treatment plant sludge. Mercury is a potential contaminant of concern in the 100 Area.	SW-9, SS-8, SS-10
Radionuclide Emissions from DOE Facilities (except Airborne Radon-222, and Radon-220)	40 CFR §61.92	A	Prohibits emissions of radionuclides to the ambient air exceeding an effective dose equivalent of 10 mrem per year.	Applicable to incinerators and other remedial technologies where air emission may occur.	SW-4, SW-7, SW-9, SS-4, SS-8, SS-10
Emission Standards for Asbestos for Waste Disposal Operations for Demolition and Renovation	40 CFR §61.150	A	States there must either be no visible emissions to the outside air during the collection, processing (including incineration), packaging, or transporting of any asbestos-containing waste material generated by the source, or specified waste treatment methods must be used.	Applicable to recovery and handling of asbestos wastes.	SW-4, SW-7, SW-9

Table 2-8 Potential Federal Action-Specific ARAR (page 3 of 7)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Asbestos Standard for Active Waste Disposal Sites	40 CFR §61.154	A	States there must either be no visible emissions to the outside air during the collection, processing (including incineration), packaging, or transporting of any asbestos-containing waste material generated by the source, or specified waste treatment methods must be used.	Applicable to landfill disposal of asbestos.	SW-4, SW-9
Department of Transportation	49 CFR Subpart C	A	Establish requirements for transportation of hazardous waste including labeling, marking, and placarding for shipment.	Applicable when hazardous wastes must be transported off-site or on public roadways.	SW-4, SW-9, SS-4, SS-10
Federal Water Pollution Control Act (FWPCA), as amended by the Clean Water Act of 1988 (CWA)	33 U.S.C. 1251 et seq.		Creates the basic national framework for water pollution control and water quality management in the United States.	Applicable to discharges of pollutants to navigable waters.	
The National Pollutant Discharge Elimination System (NPDES)	40 CFR Part 122	A	Part 122 covers establishing technology-based limitations and standards, control of toxic pollutants, and monitoring of effluent to assure limits are not exceeded.	Applicable if remediation includes wastewater discharge; also applies to storm water runoff associated with industrial activities. Effluent limitations established by EPA are included in NPDES permit.	SW-3, SW-4, SW-7, SW-9, SS-3, SS-4, SS-10
NPDES Criteria and Standards	40 CFR §125.104		Best management practices program shall be developed in accordance with good engineering practices.		
Discharge of Oil	40 CFR Part 110	A	Prohibits discharge of oil that violates applicable water quality standards or causes a sheen of oil on water surface.	Runoff from site will need control for oily water discharge to waters of the United States.	All
Solid Waste Disposal Act as amended by the Resource Conservation and Recovery Act (RCRA)	40 U.S.C. 6901 et seq.		Establishes the basic framework for federal regulation of solid waste. Subpart C of RCRA control the generation, transportation, treatment, storage, and disposal of hazardous waste through a comprehensive "cradle to grave" system of hazardous waste management techniques and requirements.	Hazardous waste generated by site remediation activities must meet RCRA generator and treatment, storage, or disposal (TSD) requirements.	
Identification and Listing of Hazardous Waste	40 CFR Part 261 [WAC 173-303-016]	A	Identifies by both listing and characterization, those solid wastes subject to regulation as hazardous wastes under Parts 261-265, 268, 270, 271, and 124.	Applicable if remediation techniques result in generation of hazardous wastes.	SW-4, SW-9, SS-4, SS-8, SS-10

Table 2-8 Potential Federal Action-Specific ARAR (page 4 of 7)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Standards Applicable to Generators of Hazardous Waste	40 CFR Part 262 [WAC 173-303]		Describes regulatory requirements imposed on generators of hazardous wastes who treat, store, or dispose of the waste on-site.	Applicable if remediation techniques result in generation of hazardous waste.	
Accumulation Time	40 CFR §262.34 [WAC 173-303-200]	A	Allows a generator to accumulate hazardous waste on-site for 90 days or less without a permit, provided that all waste is containerized and labeled.	Hazardous waste removed from the 100-Area operable units, and waste treatment residues, are subject to the 90-day generator accumulation requirements if the waste is stored on site for 90 days or less. If hazardous waste is stored for more than 90 days, the full permitting standards for TSD facilities must be met.	SW-4, SW-9, SS-4, SS-8, SS-10
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	40 CFR Part 264 [WAC 173-303]		Establishes requirements for operating hazardous waste treatment, storage, and disposal facilities.	Applies to facilities put in operation since November 19, 1980. Facilities in operation before that date and existing facilities handling newly regulated wastes must meet similar requirements in 40 CFR Part 265. Applies if remediation technique results in on-site treatment, storage, or disposal of hazardous waste.	
General Facility Standards	40 CFR §§264.10- 264.18 [WAC 173-303-060; 173-303-310; 173-303-320; 173-303-330]	A	EPA ID number, notice, waste analysis, security, inspections, personnel training, ignitable, reactive, or uncompatible wastes, location standards, and construction QA.		SW-9, SS-8, SS-10
Preparedness and Prevention	40 CFR §§264.30- 264.37 [WAC 173-303-340]	A	Facility design; required equipment; testing and maintenance of equipment; alarms and access to communications; required aisle space; agreements with state emergency response teams, equipment suppliers; facility tours for fire and police department.		SW-9, SS-8, SS-10
Contingency Plan and Emergency Procedures	40 CFR §§264.50- 264.56 [WAC 173-303-350; 173-303-360]	A	Written plans for emergency procedures and named coordinator.	Applicable for active sites, reduced or eliminated for closed sites.	SW-9, SS-8, S-10

Table 2-8 Potential Federal Action-Specific ARAR (page 5 of 7)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Closure	40 CFR §§264.111-264.116 [WAC 173-303-610]	A	Performance standard which controls, minimizes, or eliminates, to the extent necessary to protect human health and the environment, postclosure escape of chemicals; closure plan; time limits; disposal or decontamination of equipment, structures, soils; certification of closure survey plat. All contaminated equipment, structures, and soils must be properly disposed.		SW-9, SS-8, SS-10
Postclosure	40 CFR §§264.117-264.120 [WAC 173-303-610]	A	Postclosure care must begin after completion of closure and continue for 30 years. During this period, the owner or operator must comply with all postclosure requirements, including maintenance of cover, leachate monitoring, and groundwater monitoring.	Applicable to waste remaining in place after closure. Requires postclosure care and monitoring to ensure elimination of escape of hazardous constituents, leachate, and contaminated runoff.	SW-9, SS-8, SS-10
Container Storage	40 CFR §§264.170-264.178 [WAC 173-303-160-173-303-161]	A	Condition of containers; compatibility of waste with containers; container management; inspections; containment; special requirements for ignitable or reactive wastes.	May be applicable if container storage is to occur. Inspection requirements may be in potential conflict with ALARA requirements.	SW-4, SW-9, SS-4, SS-8, SS-10
Incineration	40 CFR §§264.340-264.351 [WAC 173-303-670]	A	Waste analysis; performance standards; specified principal organic hazardous constituents; incinerator permit; monitoring and inspections; closure.	Applicable if remediation technique includes incineration in hazardous waste incinerators, boilers, or industrial furnaces.	SS-8
Corrective Action for Solid Waste Management Units	40 CFR 264.552	A	Establishes provisions for corrective action management units (CAMU). A CAMU is an area within a facility that is designated by the Regional Administrator for the purpose of implementing corrective action requirements. A CAMU is used to manage remedial wastes from corrective actions.		SW-4, SW-9, SS-4, SS-10

Table 2-8 Potential Federal Action-Specific ARAR (page 6 of 7)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Land Disposal Restrictions (LDR)	40 CFR Part 268 [WAC 173-303-140- WAC 173-303-141]	A	Generally prohibits placement of restricted RCRA hazardous wastes in land-based units such as landfills, surface impoundments, and waste piles. Prohibits storage of restricted waste for longer than one year unless the owner/operator can prove storage is necessary to facilitate proper recovery, treatment, or disposal.	Applicable unless wastes have been treated, treatment has been waived, a treatment variance has been set for the waste, an equivalent treatment method petition has been approved, a no-migration petition has been approved, or the waste has been delisted.	
Treatment Standards	40 CFR §§268.40- 268.44 [WAC 173-303-140]	A	Establishes treatment standards that must be met prior to land disposal.	Applicable if wastes contain RCRA hazardous constituents.	SW-4, SW-9, SS-4, SS-10
Prohibitions on Storage	40 CFR §268.50 [WAC 173-303-141]	A	The storage of hazardous waste restricted from land disposal under RCRA Section 3004 and 40 CFR 268, Subpart C, is prohibited unless wastes are stored in tanks and containers by a generator or the on-site operator of a TSD facility solely for the purpose of accumulation of such quantities as to facilitate proper treatment or disposal. TSD facility operators may store wastes for up to one year under these circumstances.		SW-4, SW-9, SS-4, SS-10
Toxic Substances Control Act (TSCA), as amended	15 U.S.C. 2601 et seq.				
Regulation of Polychlorinated Biphenyls (PCBs)	40 CFR Part 761	A	For spills occurring after May 4, 1987, spillage or disposal must be reported to EPA. Unless otherwise approved, PCBs at concentrations of 50 ppm or greater must be treated in an incinerator. Spills that occurred before May 4, 1987 are to be decontaminated to requirements established at the discretion of the EPA.	PCBs may have been disposed of in the landfill sites in electrical capacitors or transformers.	All

Table 2-8 Potential Federal Action-Specific ARAR (page 7 of 7)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Uranium Mill Tailings Radiation Control Act of 1978	Pub. L. 95-604, as amended		Establishes controls of residual radioactive material at processing and depository sites.		
Health and Environmental Protection Standards for Inactive Uranium Processing Sites	40 CFR Part 192 Subpart A	R&A	Requires remedial action of residual radioactive material to be effective for at least 200 years.	Although Hanford is not a site designated by the Act, requirements of the Act are relevant and appropriate to the site.	All

*NOTE: A = Applicable, R&A = Relevant and Appropriate

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Table 2-9 Potential State Action-Specific ARAR (page 1 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Department of Ecology	43.21A RCW		Vests the Washington Department of Ecology with the authority to undertake the state air regulation and management program.		
Air Pollution Regulations	WAC 173-400		Establishes requirements for the control and/or prevention of the emission of air contaminants.	Applicable if emission sources are created during remedial action.	
Standards for Maximum Emissions	WAC 173-400-040	A	Requires best available control technology be used to control fugitive emissions of dust from materials handling, construction, demolition, or any other activities that are sources of fugitive emissions. Restricts emitted particulates from being deposited beyond Hanford. Requires control of odors emitted from the source. Prohibits masking or concealing prohibited emissions. Requires measures to prevent fugitive dust from becoming airborne.	Applicable to dust emissions from cutting of concrete and metal and vehicular traffic during remediation.	SW-3, SW-4, SW-7, SW-9, SS-3, SS-4, SS-8, SS-10
Emission Standards for Combustion and Incineration	WAC 173-400-050	A	Restricts operation of incinerators to daylight hours unless otherwise authorized.	Applicable if incineration is part of the remedial action.	SW-9, SS-8, SS-10
Emission Limits for Radionuclides	WAC 173-480		Controls air emissions of radionuclides from specific sources.	Applicable to remedial activities that result in air emissions.	
New and Modified Emission Units	WAC 173-480-060	A	Requires the best available radionuclide control technology be utilized in planning constructing, installating, or establishing a new emission unit.	Applicable to remedial actions that result in air emissions.	SW-4, SW-7, SW-9, SS-4, SS-8, SS-10

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Table 2-9 Potential State Action-Specific ARAR (page 2 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Washington Clean Air Act	RCW 70.94				
Controls for New Sources of Toxic Air Pollutants	WAC 173-460		Establishes systematic control of new sources emitting toxic air pollutants.		
Demonstrating Ambient Impact Compliance	WAC 173-460-080	A	Requires the owner or operator of a new source to complete an acceptable source impact level analysis using dispersion modeling to estimate maximum incremental ambient impact of each Class A or B toxic air pollutant. Establishes numerical limits for small quantity emission rates.	Applicable to remedial alternative with the potential to release toxic air pollutants.	SW-4, SW-7, SW-9, SS-4, SS-8, SS-10
Hazardous Waste Management Act of 1976 as amended in 1980 and 1983[1]	70.105 RCW		Establishes a statewide framework for the planning, regulation, control, and management of hazardous waste.		
Dangerous Waste Regulations	WAC 173-303		Establishes the design, operation, and monitoring requirements for management of hazardous waste.	Includes requirements for generators of dangerous waste. Dangerous waste includes the full universe of wastes regulated by WAC 173-303 including extremely hazardous waste.	
Siting Criteria	WAC 173-303-282	A	Prohibits location of a dangerous waste management facility within a 100-year floodplain or a land-based facility within a 500-year floodplain. Prohibits locating facilities within 500 feet of a fault with displacement during the Holocene. Establishes further siting criteria that supplement federal requirements.	Exceeds requirements of 40 CFR §264.18.	SW-9, SS-8, SS-10
Incinerators	WAC 173-303-670	A	Requires incinerators burning dangerous waste to destroy designated byproducts so that the total mass emission rate of the byproducts is no more than .01 percent of the total mass feed rate of principal organic dangerous constituents fed into the incinerator.	Exceeds requirements in 40 CFR 264.343.	SW-9, SS-8, SS-10

[1]The Hazardous Waste Management Act and regulations pursuant to the Act provide the statutory and regulatory basis for state authorization to implement RCRA. State of Washington regulations that are equivalent to RCRA regulations are cited in brackets in the federal ARARs. The WAC 173-303 regulations cited in this section are those judged to be more stringent than RCRA regulations.

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Table 2-9 Potential State Action-Specific ARAR (page 3 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Model Toxics Control Act	70.105D RCW		Authorizes the state to investigate releases of hazardous substances, conduct remedial actions, carry out state programs authorized by federal cleanup laws, and take other actions.		
Hazardous Waste Cleanup Regulations	WAC 173-340		Addresses releases of hazardous substances caused by past activities, and potential and ongoing releases from current activities.	Applicable to facilities where hazardous substances have been released, or there is a threatened release that may pose a threat to human health or the environment.	
Selection of Cleanup Actions	WAC 173-340-360	R&A	Establishes cleanup requirements to include in cleanup plans. Identifies technologies to be considered for remediation of hazardous substances.		All
Cleanup Actions	WAC 173-340-400	R&A	Ensures that the cleanup action is designed, constructed, and operated in accordance with the cleanup plan and other specified requirements.		All
Institutional Controls	WAC 173-340-440	R&A	Requires physical measures such as fences and signs to limit interference with cleanup, and legal and administrative mechanisms to enforce them.		SW-2, SW-3, SW-4, SW-7, SW-9, SS-2, SS-3, SS-4, SS-8, S-10
Solid Waste Management Act	70.95 RCW		Establishes a statewide program for solid waste handling, recovery, and/or recycling.	Applicable if management of solid waste occurs during remediation. Solid waste controlled by this Act includes garbage, industrial waste, construction waste, ashes, and swill.	
Minimum Functional Standards for Solid Waste Handling	WAC 173-304		Establishes requirements to be met statewide for the handling of all solid waste.		
On-site Containerized Storage, Collection, and Transportation Standards	WAC 173-304-200	R&A	Sets requirements for containers and vehicles to be used on site; requires monthly inspections and retention of inspection records for at least two years.		SW-2, SW-3, SW-4, SW-7, SW-9, SS-2, SS-3, SS-4, SS-8, SS-10

Table 2-9 Potential State Action-Specific ARAR (page 4 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Solid Waste Incinerator Facilities	WAC 173-434		Establishes emissions standards, design requirements, and performance standards for solid waste incinerator facilities		
Emissions Standards	WAC 173-434-130	A	Limits particulate emissions from each stack to <0.046 g/dry m³ for systems greater than 250 ton/day and <0.069 g/dry m³ for systems under 250 ton/day. Limits both hydrogen chloride and sulfur dioxide to less than 50 ppm each per stack. Visual opacity shall not exceed 5% average for more than 6 minutes in 60 minutes. Limits transmissometer opacity to 10% and requires reasonable precautions to limit fugitive emissions.	Applicable to remedial actions involving incineration.	SW-9, SS-8, SS-10
Water Pollution Control Act	90.48 RCW		Prohibits discharge of polluting matter in waters.		
State Waste Discharge Permit Program	WAC 173-216		Implements a state permit program, applicable to the discharge of waste materials from industrial, commercial, and municipal operations into the ground and surface waters of the state. Excludes discharges under NPDES and underground injection control programs.		
Permit Terms and Conditions	WAC 173-216-110	R&A	Requires the use of all known, available, and reasonable methods of prevention, control, and treatment.		All

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Table 2-9 Potential State Action-Specific ARAR (page 5 of 5)

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Water Well Construction Act	18.104 RCW				
Standards for Construction and Maintenance of Wells	WAC 173-160	A	Establishes minimum standards for design, construction, capping, and sealing of all wells; sets additional requirements including disinfection of equipment, abandonment of wells, and quality of drilling water.	Applicable if water supply wells, monitoring wells, or other wells are utilized during remediation.	SW-2, SW-3, SW-7, SS-2, SS-3, SS-8

*NOTE: A = Applicable, R&A = Relevant and Appropriate

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Table 2-10 Potential Action-Specific TBC

Description	Citation	Requirements	Remarks	Alternatives Potentially Affected
Benton-Franklin-Walla Walla Counties Air Pollution Control Authority	General Regulation 80-7	Establishes a regional program of air pollution prevention and control.	These county regulations are authorized by the state Clean Air Act.	
Monitoring and Special Reporting	Section 400-120	Monitoring of any source may be required.		SW-2, SW-3, SW-4, SW-7, SW-9, SS-2, SS-3, SS-4, SS-8, SS-10
Residual Radioactive Material as Surface Contamination	U.S. NRC Regulatory Guide 1.86	Sets contamination guidelines for release of equipment and building components for unrestricted use, and if buildings are demolished, shall not be exceeded for contamination in the ground.		All
U.S. Department of Energy Orders				
Discharge of Treatment System Effluent	DOE 5400.xy	Treatment systems shall be designed to allow operators to detect and quantify unplanned releases of radionuclides, consistent with the potential for off-property impact.	Required of all DOE-controlled facilities where radionuclides might be released as a consequence of an unplanned event.	SW-7, SW-9, SS-8, SS-10
Radiation Protection for Occupational Workers	DOE 5480.11 Section 9a	Establishes radiation protection standards and program requirements to protect workers from ionizing radiation.		All
Safety Requirements for the Packaging of Fissile and Other Radioactive Materials	DOE 5480.3 Sections 7 and 8	Establishes requirements for packaging and transportation of radioactive materials for DOE facilities		SW-4, SW-9, SS-4, SS-10
Radioactive Waste Management	DOE 5820.2A Chapters III and IV	Establishes policies and guidelines by which DOE manages radioactive waste, waste by-products, and radioactive contaminated surplus facilities. Disposal shall be on the site at which it was generated, if practical, or at another DOE facility. DOE waste containing byproduct material shall be stored, stabilized in place, and/or disposed of consistent with the requirements of the residual radioactive material guidelines contained in 40 CFR 192.		All
Department of Ecology Liquid Effluent Consent Order	DE 91NM-177	Requires discharges of liquid effluent to the soil column to be eliminated, treated, or otherwise minimized.		SW-9, SS-8, SS-10

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3.0 WASTE SITE GROUP DEVELOPMENT

As discussed in Section 1.4, the 100 Area contains multiple waste sites (sources). To facilitate the plug-in approach, these sources are assembled into groups consistent with the analogous site approach. These groups are based on similar characteristics such as, physical structure, function, and impacted media. Similarities and differences between the sites within each group are then evaluated and compared to develop a group profile which is representative of the associated sites. The group profiles will form the basis for the subsequent development of IRM alternatives (including enhancements) applicable to each site group (Section 4.0).

3.1 GROUP DESCRIPTIONS

This FFS addresses the site groups identified in Figure 1-4, with the exception of the septic systems and special use burial grounds. These groups are not included because they are not represented by any current IRM candidate sites in the 100 Area. Retention basins, outfall structures, and pipelines represent those sites which transferred the contaminated reactor effluent for ultimate disposal to process effluent trenches or the Columbia River. Trenches, cribs, and french drains are those sites which were used for the ultimate disposal of contaminated liquid wastes. Solid waste burial grounds and D&D sites represent the contaminated solid waste sites addressed by this FFS. A description of each group is given below.

3.1.1 Retention Basins

The 100 Area retention basins were rectangular concrete or circular steel structures used to retain cooling water effluent from the reactor for radioactive decay and thermal cooling prior to discharge to the river. Some of the basins were baffled to provide separate compartments. In initial operations, effluent was directed to only one side of the basin at a time which allowed effluent contaminated by ruptured fuel elements to be diverted to other disposal facilities such as cribs and trenches. However, temperature differentials between the basin halves resulted in cracks and subsequent leakage. This leakage, coupled with increased production rates, forced simultaneous use of the retention basin compartments. Following the reactors final shutdown, some of the retention basins were partially demolished and the rubble buried in-place. The basins have also been used for disposal of contaminated piping and other demolition materials.

3.1.2 Outfall Structure

Outfall structures were compartmentalized boxes used to direct the liquid effluent from the retention basin to the river pipelines for discharge to the middle of the Columbia River. The structures were constructed of reinforced concrete with concrete or rip-rap spillways (spillways were used only in case of overflow). Most of the outfalls have been demolished to near-grade level and backfilled. The outfall structures have not been decontaminated or cleaned out in a manner similar to the D&D facilities, therefore some contamination may still exist at the sites. Effluent was normally discharged via the outfall and river pipelines; however effluent discharges sometimes overflowed the outfall structure and exceeded the capacity of the spillways resulting in overflow to surrounding soils down to the river's edge.

Although the outfall structures were originally on the IRM pathway, they have been recently designated for an expedited response action. The *100 Area River Effluent Pipelines Expedited Response Action Proposal* (DOE-RL 1994a) indicates that the 100 Area outfall structures will be addressed concurrently with the river pipelines. The outfall structures are therefore removed from the IRM pathway and are not addressed further in the FFS.

3.1.3 Pipelines

Effluent pipelines ran from the reactors to the retention basins, from the retention basins to the outfall structures, and from the outfall structures to the discharge point in the middle of the Columbia River. The 100 Area contained approximately 18,900 m (62,000 ft) of effluent pipeline ranging in size from 0.3 to 2.1 m (12 to 84 in.) in diameter (Adams et al. 1984). The pipelines were constructed of carbon steel, reinforced concrete, or sometimes vitreous tile. The pipelines included manholes, junction boxes, tie-lines between parallel legs, and valves. Most of the on-land pipelines were buried, although a portion of the effluent line in the 100 F Area was aboveground.

This FFS addresses only those pipelines which extend from the reactor to the retention basin, and from the retention basin to the outfall structures. The sections of pipeline which extend to the middle of the Columbia River from the outfall structures are being addressed as an expedited response action. An engineering evaluation and cost assessment for addressing the river pipelines has been performed and is documented in *100 Area River Effluent Pipelines Expedited Response Action Proposal* (DOE-RL 1994a).

Some leaks have occurred along the pipelines, mainly at the junction boxes of the steel and concrete lines and the rubber joints of the tile lines (Dorian and Richards 1978). Contamination associated with the effluent lines is primarily in these leakage areas and in the accumulated sludge in the pipes. Contaminated soil associated with the leakage areas is considered only if pipeline leakage is documented by data indicating soil contamination. Otherwise, only the pipeline and associated sludges are considered as the contaminated media.

3.1.4 Trenches

Trenches are unlined, open excavations which were used for direct soil disposal of contaminated liquids and sludges. Trenches were used for various disposal activities described below:

- <u>Sludge Trenches</u> - used for disposal of highly contaminated sludge which had accumulated on the floor of the retention basins.

- <u>Fuel Storage Basin Trenches</u> - used for one-time events where shielding water from the fuel storage basin was discharged due to excessive levels of contamination.

- <u>Process Effluent Trenches</u> - used for disposal of highly contaminated cooling water which was diverted from the retention basins for direct soil disposal.

3.1.5 Cribs/French Drains

Cribs were buried, generally rock-filled, structures. Early cribs were typically open-bottomed, and constructed from wooden timbers. The cribs generally ranged in area from 9.3 to 18.6 m^2 (100 to 200 ft^2). French drains were generally gravel-filled, steel, concrete or vitreous clay pipe. These were 0.9 to 1.2 m (3 to 4 ft) in diameter and ranged from 0.9 to 6.1 m (3 to 20 ft) deep. Cribs and french drains are considered similar because of their relatively small size, associated structures, disposal volumes, and frequency of use. The crib/french drain sites are divided into the following four groups based on associated waste streams.

- <u>Pluto Cribs</u> - received highly contaminated reactor cooling water that was flushed directly from process tubes affected by fuel cladding failures.

- <u>Dummy Decontamination Crib/French Drains</u> - generally received waste associated with the decontamination of laboratory or reactor equipment such as dummy fuel elements.

- <u>Seal Pit Cribs</u> - received condensate from the reactor filter building operations.

- <u>Special Cribs</u> - associated with a unique facility of project, receiving a site-specific waste stream. These sites require individual analyses and no group profile is developed.

3.1.6 Solid Waste Burial Grounds

Solid waste burial grounds which serve the reactor facilities consisted of a series of trenches, pits, vertical pipes, and/or vault-like structures. The burial grounds ranged in size with the smallest being only a few feet wide and a few feet long to the largest being about

6.1 m (20 ft) deep, 91 m (300 ft) long, and 2.4 m (8 ft) wide (at the bottom). The deep, narrow trenches contained contaminated large equipment; the pits and pipes were used for small, contaminated reactor hardware such as thermocouple stringers and horizontal control rod tips. A typical burial trench consisted of layers of hard waste (metal components such as irradiated process tubes and fuel charge spacers) and soft waste (such as contaminated paper, plastic, and clothing). Hard waste was usually placed in the bottom of the trench. Soft waste makes up more than 75% of the volume in the trenches but contains <1% of the radioactive inventory (Adams et al. 1984).

Each reactor had an associated burial ground. Miller and Wahlen (1987) estimated the total radionuclide inventory from reactor operations for these burial grounds to be about 4,000 curies, mostly from cobalt-60 and nickel-63. Metallic wastes include boron, cadmium, graphite, lead, lead-cadmium alloy, and mercury.

3.1.7 Decontaminated and Decommissioned Facilities

To reduce the potential spread of radioactive contamination from the reactors and associated facilities, DOE began a program of D&D of buildings and facilities after the reactor areas were retired. Most of the contaminated buildings and facilities have been demolished and were buried in place, disposed of in the clearwells associated with the water treatment facility (clean material only), or taken to the 200 Areas for burial. Clean wooden buildings and equipment were salvaged and uncontaminated buildings were converted for new programs or storage. In some instances, new buildings were constructed over the demolished building locations. The facilities which have been demolished and buried in place are considered similar to burial grounds, thus they follow the IRM pathway.

The D&D activities included removing or fixing smearable contamination, and sampling to determine residual contamination levels. The residual contamination was subject to a comparison against allowable residual contamination levels (ARCL) (a method to determine if the level of residual contamination is within release limits). The methodology for determining the ARCL is documented in Kennedy and Napier (1983). The objective of this analysis is to determine whether radioactively contaminated sites require further decontamination or remedial action prior to release. For unrestricted release of a site, a general limit of 10 mrem/yr was used. Many of the facilities addressed by D&D were released to an unrestricted status.

3.2 GROUP PROFILES

Based on the data from the 100-BC-1, 100-HR-1, and 100-DR-1 Source Operable Unit LFI (DOE-RL 1993c, DOE-RL 1993d, and DOE-RL 1993b), and the refined COPC discussed in Section 2.6, a profile for each waste site group has been developed. The 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units are considered adequately representative of the 100 Area waste sites, therefore the IRM candidate sites from these operable units are used to define the group profile. Site-specific deviations from these profiles will be identified and addressed in each operable unit-specific FFS document to ensure that characteristics not represented by the group profile defined here are given adequate consideration.

The group profile consists of waste site characteristics such as extent of contamination, contaminated media/material, maximum concentrations of the refined COPC, and a determination of exceedance of allowable soil concentrations under a reduced infiltration scenario. The profiles perform two functions; first, they establish a baseline for determining appropriate remedial alternatives for the waste site group (i.e., presence of contaminants such as organics requires special treatment enhancements), secondly, as a data base for determining costs and durations of remedial activities (i.e., contaminated volume impacts cost of disposal and duration of excavation). The profile parameters are defined below, followed discussion of the group profiles which are detailed in Table 3-1.

Extent of Contamination/Selection of Representative Waste Site

The extent of contamination evaluations consist of determinations of contaminated volume, length, width, area, and thickness. The values for these parameters are based on a comparison of all IRM candidate sites within a group. The extent of contamination from the site with the greatest contaminated volume is chosen to represent the extent of contamination for the group. Volume, length, width, and area do not necessarily impact the determination of appropriate remedial alternatives, however they are important considerations for developing costs and durations of remedial actions. By using the site with the greatest contaminated volume, the cost and duration of the remedial action represents a worst-case scenario for the group. In addition, it should be noted that site-specific costs and durations are determined in each operable unit-specific FFS. In addition, thickness of the contaminated lens impacts the implementability of in situ actions such as vitrification which has a limited vertical extent of influence.

Contaminated Media/Material

Contaminated media and material are defined by any media and material present at any IRM candidate site within a group. Structural materials such as steel, concrete, and wooden timbers influence the applicability of remedial alternatives, as well as equipment needed for actions such as removal. Presence of soils and sludges are necessary for implementation of treatment options such as soil washing. Presence of solid waste media impacts material handling considerations and may require remedial alternatives which vary from sites with contaminated soil.

Refined COPC/Maximum Concentrations

Refined COPC and associated maximum concentrations for a group are determined by first compiling all refined COPC and maximum concentrations detected for each IRM candidate site within a group. Constituents and associated maximum concentrations which are present in the majority of the sites (more than half) are considered to be refined COPC for the group. The associated maximum concentration for that constituent is the highest concentration detected above PRG in any of the IRM candidate sites. Those constituents which are present in the minority of the sites (less than half) are addressed site-specifically in each operable unit-specific FFS. Refined COPC may influence the applicability of remedial alternatives. For instance, presence of radioactive contaminants may allow natural decay to be a consideration in determining appropriate remedial actions, organic contaminants may require that enhancements such as thermal desorption be added to a treatment system, and the presence of cesium-137 influences the effectiveness of treatment alternatives such as soil washing.

Reduced Infiltration Concentration

The reduced infiltration concentration is a level which is considered protective of groundwater under a scenario where hydraulic infiltration is limited by the application of a surface barrier. The derivation of this concentration is documented in Appendix A. The maximum concentration detected is compared to the allowable reduced infiltration concentration. Impact to groundwater will not be mitigated by containment alternatives for waste sites where concentrations of constituents in soil exceed the reduced infiltration concentrations.

In addition to being the basis for the detailed and comparative analysis performed in this FFS, and facilitating the use of the plug-in approach, development of a group profile aids in the implementation of the analogous site approach. The analogous site approach allows conditions from a site, or sites with data to be assumed for sites without data as long as the sites are analogous (i.e., within the same group). This minimizes the amount of site-specific investigations required to define waste site characteristics. The group profiles presented herein can serve as a basis for development of site-specific conditions addressed in each operable unit specific FFS. For the site-specific evaluation, the following methodology is used when assessing data from analogous waste sites:

- Contaminants:
  - assume contaminant types (radionuclides, inorganic, or organics) are the same for all sites within a group unless site-specific data indicates otherwise
  - if a site has no data, use contaminant inventory (specific constituents) from the group profile.

- Extent of contamination:
  - determine extent of contamination based only on site-specific data when available
  - if no data are available, use group profile data to assume extent of contamination.

The following sections discuss the profile for each waste site group. The specific elements of each profile are presented in Table 3-1.

3.2.1 Retention Basins

The extent of contamination for retention basins is defined by site 116-DR-9. The volume estimate for this site is documented in the 100-DR-1 Operable Unit FFS (DOE-RL 1994b). Representative costs and durations of interim actions for the retention basin group are based on the dimensions of 116-DR-9. The contaminated media includes soils, sludges, concrete, and steel. Radionuclide and inorganic contaminants are present, some at levels which exceed the reduced infiltration concentrations.

3.2.2 Sludge Trenches

The extent of contamination for sludge trenches is defined by site 107-D #2. The volume estimate for this site is documented in the 100-DR-1 Operable Unit FFS (DOE-RL 1994b). Representative costs and durations of interim actions for the sludge trench group are based on the dimensions of 107-D #2. The contaminated media include soils and sludges. Contaminants and their associated concentrations are assumed from the retention basins because no data has been collected at any of the sludge trenches in the 100 Area. This is appropriate since the sludge originated from the retention basins.

3.2.3 Fuel Storage Basin Trenches

The extent of contamination for fuel storage basin trenches is defined by site 116-D-1A. The volume estimate for this site is documented in the 100-DR-1 Operable Unit FFS (DOE-RL 1994b). Representative costs and durations of interim actions for the fuel storage basin trench group are based on the dimensions of 116-D-1A. The contaminated media consists only of soil. Radionuclide and inorganic contaminants are present, some at levels which exceed the reduced infiltration concentrations.

3.2.4 Process Effluent Trenches

The extent of contamination for process effluent trenches is defined by site 116-C-1. The volume estimate for this site is documented in the 100-BC-1 Operable Unit FFS (DOE-RL 1994c). Representative costs and durations of interim actions for the process effluent trench group are based on the dimensions of 116-C-1. The contaminated media consists only of soil. Radionuclide and inorganic contaminants are present, some at levels which exceed the reduced infiltration concentrations.

3.2.5 Pluto Cribs

The extent of contamination for pluto cribs is defined by site 116-D-2A. The volume estimate for this site is documented in the 100-DR-1 Operable Unit FFS (DOE-RL 1994b). Representative costs and durations of interim actions for the pluto crib group are based on the dimensions of 116-D-2A. The contaminated media consists of soil and wooden timbers.

Only one contaminant, radium-226, is above PRG, and is at a level which exceeds the reduced infiltration concentration.

3.2.6 Dummy Decontamination Cribs/French Drains

The extent of contamination for dummy decontamination cribs/french drains is defined by site 116-B-4. The volume estimate for this site is documented in the 100-BC-1 Operable Unit FFS (DOE-RL 1994c). Representative costs and durations of interim actions for the dummy decontamination cribs/french drain group are based on the dimensions of 116-B-4. The contaminated media consists of soil and steel. Radionuclide contaminants are present, however none exceed the reduced infiltration concentrations.

3.2.7 Seal Pit Cribs

None of the seal pit cribs identified as IRM candidates have constituents with concentrations which exceeded PRG. Because of this, there is no contaminated volume for any of the sites, thus no representative site was selected and no profile parameters were defined.

3.2.8 Pipelines

The extent of contamination for pipelines is defined by the pipelines in the 100 B/C Area. The volume estimate for this site is documented in the 100-BC-1 Operable Unit FFS (DOE-RL 1994c). Representative costs and durations of interim actions for the pipeline group are based on the dimensions of 100 B/C pipelines. The contaminated media consists of soil, steel, and concrete. Radionuclide contaminants are present, and Table 3-1 indicates plutonium-239/240 as exceeding the reduced infiltration concentration. This exceedance is eliminated, however, because the waste containing this concentration is in the sludge within the pipeline and is assumed to be immobile. Therefore, there are no constituents considered as a potential threat to groundwater under a reduced infiltration scenario.

3.2.9 Burial Grounds

The extent of contamination for burial grounds is defined by site 118-D-4A. The volume estimate for this site is documented in the 100-DR-1 Operable Unit FFS (DOE-RL 1994b). Representative costs and durations of interim actions for the burial ground group are based on the dimensions of 118-D-4A. The contaminated media consists only of solid waste. Radionuclide, inorganic, and organic contaminants are expected to be present, however no characterization data is available. It is assumed that burial grounds contain immobile forms of waste thus, no contaminants are assumed to exceed the reduced infiltration concentrations. This assumption, originally developed in RI/FS work plans in the absence of site-specific data, is centered around the concept that the vertical extent of contamination is limited to the bottom of the burial, and that the contamination is fixed to the solid waste in the burial ground and not in the surrounding soils.

3.2.10 Decontaminated and Decommissioned Facilities

Due to the D&D process and release methodology discussed in Section 3.1.7, it is assumed that sites which have been subject to D&D pose no threat warranting an interim action. Site-specific reports for all sites that have undergone D&D are available. These reports document the D&D activities and substantiate the release of the sites under the ARCL methodology. No representative site has been selected and no profile parameters are defined.

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Table 3-1 Waste Site Group Profiles (page 1 of 4)

Waste Site Group	General Group Characteristics (a)								
	Extent of Contamination					Media/ Material	Refined COPC	Maximum Concentration Detected	Are Reduced Infiltration Concentrations Exceeded?
	Volume (m^3)	Length (m)	Width (m)	Area (m^2)	Thickness (m)				
Retention Basins	260,414	210.3	101.5	21345.0	12.2	Soil	Radionuclides	pCi/g	
						Concrete	^{14}C	429	NO
						Steel	^{137}Cs	3250	NO
						Sludge	^{60}Co	4390	NO
							^{152}Eu	29600	NO
							^{154}Eu	9940	NO
							^{238}Pu	9.4	NO
							$^{239/240}Pu$	340	NO
							^{90}Sr	770	NO
							^{228}Th	4.4	NO
							Inorganics	mg/kg	YES
							Arsenic	47	NO
							Cadmium	1.2	YES
							Chromium VI	609	NO
							Lead	564	
Sludge Trenches	2316.0	38.1	15.2	572	4.0	Sludge	Radionuclides	assumed from	NO
							^{14}C	retention basin	NO
							^{137}Cs	data	NO
							^{60}Co		NO
							^{152}Eu		NO
							^{154}Eu		NO
							^{238}Pu		NO
							$^{239/240}Pu$		NO
							^{90}Sr		NO
							^{228}Th		NO
							Inorganics		
							Arsenic		YES
							Cadmium		NO
							Chromium VI		YES
							Lead		NO

Table 3-1 Waste Site Group Profiles (page 2 of 4)

Waste Site Group	General Group Characteristics (a)								
	Extent of Contamination					Media/ Material	Refined COPC	Maximum Concentration Detected	Are Reduced Infiltration Concentrations Exceeded?
	Volume (m^3)	Length (m)	Width (m)	Area (m^2)	Thickness (m)				
Fuel Storage Basin Trenches	4409.0	43.3	6.7	290.0	15.2	Soil	Radionuclides ^{137}Cs ^{152}Eu $^{239/240}Pu$ ^{226}Ra Inorganics Cadmium Chromium VI Lead	pCi/g 25.7 9.72 8.30 42.8 mg/kg 1.0 108 51.9	 NO NO NO YES NO YES NO
Process Effluent Trenches	31441.0	169.8	32.6	5535.0	5.8	Soil	Radionuclides ^{137}Cs ^{152}Eu $^{239/240}Pu$ Inorganics Chromium VI	pCi/g 830.0 530 14 mg/kg 186	 NO NO NO YES
Pluto Cribs	14.4	3.1	3.1	9.6	1.5	Soil Timbers	Radionuclides ^{226}Ra	pCi/g 13	 YES
Dummy Decontamination Cribs/French Drains	3.2	1.2 (dia.)	1.2 (dia.)	1.1	2.7	Soil Steel	Radionuclides ^{137}Cs ^{60}Co ^{152}Eu ^{154}Eu $^{239/240}Pu$	pCi/g 208 268 420 45.4 8.60	 NO NO NO NO NO
Seal Pit Cribs	0.0	0.0	0.0	0.0	0.0	NA	None	NA	NA

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Table 3-1 Waste Site Group Profiles (page 3 of 4)

Waste Site Group	General Group Characteristics (a)								
	Extent of Contamination					Media/ Material	Refined COPC	Maximum Concentration Detected	Are Reduced Infiltration Concentrations Exceeded?
	Volume (m^3)	Length (m)	Width (m)	Area (m^2)	Thickness (m)				
Pipelines	302973.0	6533.0	varies	varies	varies	Soil	Radionuclides	pCi/g	
						Steel	^{137}Cs	111,000	NO
						Concrete	^{60}Co	2,810	NO
							^{152}Eu	16,800	NO
							^{154}Eu	3,410	NO
							^{155}Eu	9,420	NO
							^{63}Ni	61,800	NO
							^{238}Pu	141	NO
							$^{239/240}Pu$	2,800	YES(b)
							^{90}Sr	2,040	NO

Table 3-1 Waste Site Group Profiles (page 4 of 4)

Waste Site Group	General Group Characteristics (a)								
	Extent of Contamination					Media/ Material	Refined COPC	Maximum Concentration Detected	Are Reduced Infiltration Concentrations Exceeded?
	Volume (m^3)	Length (m)	Width (m)	Area (m^2)	Thickness (m)				
Burial Grounds	4564.0	57.9	18.3	1059	6.1	Misc. Solid Waste	<u>Radionuclides</u> ^{14}C ^{137}Cs ^{60}Co ^{152}Eu ^{154}Eu ^{3}H ^{63}Ni ^{90}Sr <u>Inorganics</u> Cadmium Lead Mercury <u>Organics</u> no specific constituents identified, but 5% of volume is assumed to be contaminated by organics	(c)	NO: assume that the burial grounds contain immobile forms of waste
Decontaminated/ Decommissioned Facilities	0.0	0.0	0.0	0.0	0.0	NA	None	NA	NA

(a) Group contaminated dimensions are based on a representative (maximum case) site. Refined contaminants of potential concern are a compilation of the maximum concentrations detected for each constituent above PRG for all sites within the 100-BC-1, 100-HR-1 and 100-DR-1 Operable Unit interim remedial measure candidate sites.
(b) This level is representative of only that waste which is in the pipeline and is not considered a potential impact to groundwater
(c) No quantitative data is available. Constituents are assumed from Miller and Wahlen 1987.
NA Not Applicable
COPC contaminant of potential concern
PRG preliminary remediation goals

4.0 DETAILED DESCRIPTION OF ALTERNATIVES

In this section, GRA and associated remedial alternatives initially identified the FS Phases 1 and 2 are refined and presented. Pursuant to the scope of this document, only those alternatives applicable to source media (i.e., soil and solid waste) are included. Specific technologies and process options which are components of the refined alternatives are presented in Section 4.1. Alternative descriptions, associated applicability criteria, and appropriate alternative enhancements are presented in Section 4.2.

4.1 DETAILED DESCRIPTION OF TECHNOLOGIES AND PROCESS OPTIONS

The technologies and process options are described in the following manner:

- Technologies are presented as originally conceptualized in the FS Phases 1 and 2 (DOE-RL 1993a). Modifications are made as necessary based on standards of practice and applicability. Details are provided to enable a complete understanding of the implementation of the technology, any limitations for its application, and any deviations necessary with respect to waste site groupings.

- Treatability studies (or similar applications) are presented to demonstrate how the technology is implemented. In addition to the technologies and process options, a discussion of innovative technology programs is presented in Section 4.1.7. These innovative technologies are in various stages of development and demonstration and may be implementable for future remedial alternatives.

4.1.1 Institutional Controls

Institutional controls retained from the FS Phases 1 and 2 (DOE-RL 1993a) include groundwater surveillance monitoring and access restrictions. Access restrictions include deed restrictions and fencing. The following sections provide a discussion on each option.

4.1.1.1 Groundwater Surveillance Monitoring. Groundwater surveillance monitoring is utilized for actions that leave contamination in place above the PRG. Groundwater surveillance monitoring is used to evaluate the long-term effectiveness of an action. The remedial actions selected as a result of this FFS will be interim actions only and will be subject to further evaluation prior to the final ROD for the operable unit. The present network of groundwater monitoring wells and sampling schedule are deemed adequate for the monitoring of impacts to groundwater. Also, added groundwater wells may not detect near-term changes from an IRM, thus a separate groundwater surveillance monitoring program is not necessary. Monitoring potential pathways and impacts to groundwater from source operable units requires coordination with the monitoring currently being performed for the groundwater operable units. Vadose zone contaminants which are deemed as having potential impact on groundwater must be included in the groundwater monitoring program.

A complete groundwater surveillance monitoring program, which includes all contaminants left in place, will be instituted upon completion of remediation within a reactor area. The implementation of such a monitoring program requires that an assessment be performed to evaluate the combined groundwater/vadose zone hydrologic system and define the current and future probable impacts to groundwater.

4.1.1.2 Deed Restrictions. Deed restrictions are legal specifications for land use. Typical deed restrictions consist of covenants against activities that may bring humans in contact with contaminants. Deed restrictions may include: provisions that prevent the use of groundwater; requirements for approval of excavations beyond a specified depth; or limitations on land use by prohibiting activities such as grazing, farming, and extended camping. The implementation of deed restrictions involves administrative resources in combination with visual monitoring (policing). Signage may accompany deed restrictions as needed to aid in understanding of the restrictions. Signage may simply include visibly posting the pertinent deed restrictions in such a way to ensure compliance. Generally, deed restrictions are required for all actions that leave contamination above the PRG in place.

4.1.1.3 Fencing. The term "fencing" is used for any type of physical barrier around a contaminated area which is constructed with the intention of limiting access. Fencing is an easily implementable technology. The effectiveness of fencing the IRM waste sites is limited. A fence provides a barrier which must be crossed to gain access to an area but cannot absolutely prevent ecological or human receptors from entering. At present, fencing is not required due to the existing security on the site. In the long term, fencing would not prevent intrusion (trespassing).

4.1.2 Removal

4.1.2.1 Description. Removal technologies entail excavation of contaminated materials, demolition of contaminated structures, and processing of materials to allow for proper treatment and/or disposal. The removal strategy allows full implementation of the observational approach for remediation of the site. To be effective and safe, removal technologies must be coupled with real time analytical field screening, dust control, efficient transportation, and disposal. Removal technologies have previously been explored for use in the 100 Areas on both a large (WHC 1991a) and small scale (DOE-RL 1994d). It is assumed that contaminated material being addressed is low activity waste (WHC 1991b). The removal technologies described are based on this assumption. High activity wastes, if encountered will be remotely handled, set in a secure area, and shielded. These wastes will then be disposed of in accordance with the *Hanford Site Solid Waste Acceptance Criteria* (WHC 1993a).

The removal process, as applied to the 100 Areas, involves the following steps (WHC 1993b):

- removal and stockpiling of clean overburden, where present, to expose the contaminated material

- excavation to remove contamination above PRG
- demolition of contaminated structures as part of or concurrent with the excavation
- dust control and real time analytical field screening during excavation
- support of nearby structures affected by excavation (where necessary)
- processing of materials removed (processing with equipment other than excavation equipment are discussed as separate technologies)
- transportation of wastes to a disposal facility
- reclamation of the site, using stockpiled material.

Excavation can be performed using conventional equipment and methods. Excavation equipment which is most appropriate for removal of the contaminated materials present in the waste sites includes excavators (backhoes), bulldozers, and wheeled loaders. For removal and processing of concrete and steel structures and pipelines the excavator can be equipped with various interchangeable attachments including demolition, processing, shear, densification, and grapple attachments. The method of removal varies according to waste site group.

Retention Basin Sites are remediated by first removing basin fill material with an excavator. Exposed concrete basin walls are demolished using an excavator equipped with either a hydraulic hammer or a pulverizer attachment. Steel basin walls are cut with an excavator equipped with shears. Demolished materials are loaded into haul trucks with an excavator using both bucket and grapple attachments. Excavation of contaminated soil then proceeds in lifts using the excavator, bulldozer, and loader (Figure 4-1). This part of the excavation is guided by in situ analytical field screening which delineates the zone of contaminated material with real time instruments. The extent of these excavations is large, requiring the equipment to work within the excavation. Haul trucks, loaded in the excavation, use ramps to enter and exit the site. Clean material is stockpiled nearby the excavation for later use in reclamation of the site.

Liquid Disposal Trench Sites are remediated by first removing any clean overburden with a bulldozer and a loader. Excavation of contaminated soil then proceeds in the same manner as the retention basin sites (Figure 4-1).

Effluent Pipelines include those between the outfall structures and the reactor building, as discussed in Section 3.1.3. The effluent pipelines are remediated by first removing any clean overburden with a bulldozer and loader. Material is then removed from either side of the pipeline with the excavator. Working from the top and side of the excavation, an excavator with a shear attachment is used to cut the pipe. Using a grapple attachment, sections of the pipe are then removed from the excavation (Figure 4-2). The excavation then proceeds as necessary to remove any contaminated soil. Ramp access to the bottom of the excavation is maintained to allow in situ monitoring. Removed sections of pipe are processed at the surface using an excavator with pulverizer or shear/densifier attachments. Processed pipe material is loaded into haul trucks with a grapple.

Crib and French Drain Sites are removed exclusively with an excavator working from the surface (Figure 4-3). If the extent of contamination is greater than the reach of the excavator arm, the site is benched and access provided to the bench.

Burial Ground Sites are remediated by first removing clean overburden with a bulldozer and loader. Buried waste is then removed with the excavator with either the bucket or grapple attachment (Figure 4-4). Oversize objects that have been removed are reduced in size at the surface using shear or densifier attachments or shipped to the disposal site intact.

Decontaminated and Decommissioned Facilities are remediated by first removing overburden and surrounding soil using an excavator with a bucket attachment. Demolition attachments, such as pulverizers or shears, are used to demolish the remaining structures. Demolished material is loaded into haul trucks with the excavator using a grapple attachment. The demolished material may either be disposed or decontaminated and recycled, as applicable. Contaminated soil beneath the structure is removed in lifts using the excavator with a bucket.

Proper dust control is essential during excavation as operations may generate significant quantities of fugitive dust. Dust control measures are provided to reduce the spread of contamination by entrainment of fugitive dust, minimize the impacts on local air quality and minimize the exposure to onsite personnel. Water sprays are the primary means for controlling fugitive dust. Water is applied to an active excavation face at the amount of approximately 1 gal/yd^2 (EPA 1985). Water is supplied to the excavation by water trucks or local hydrants. Crusting agents may be applied to active excavations prior to short term work breaks. Access ramps and haul roads will also require dust suppression. Haul roads will be constructed and maintained using soil cementing agents.

Real time analytical field screening to define the extent of contamination during excavation is an integral part of removal in the observational approach. Such an approach eliminates the need for detailed delineation of the extent of contamination prior to remediation. Such field screening requires the use of sophisticated detection equipment for in situ use and the use of onsite laboratories performing quick turn around radionuclide, inorganic, and organic analyses. Monitoring instruments include sodium iodide and hyperpure germanium gamma detectors for radionuclides, photo-ionization or flame-ionization detectors for VOC, x-ray fluorescence for metals, and hi-volume samplers for respirable dust.

Support of nearby structures may be required if the limit of the excavation impinges on the foundation of the structure or otherwise compromises the stability of the structure. Such support entails the placement of some type of excavation bracing. Applicable systems include soldier beams with horizontal timber sheeting and tiebacks. Additional measures will be required should contaminants extend beyond the boundaries of these structures.

Assuming that the contaminated soils will be disposed of onsite, safe and efficient transport will be required. such transport is considered well established technology as demonstrated at the DOE Uranium Mill Tailings Remedial Action site. It is anticipated that some project-specific design of the transport container and its lid will be required, but that such development will not be excessive. A plausible concept for the transport of soils is as follows:

- industrial transport containers carried by highway trucks located at the excavation
- loaded material is wetted then transported to a local (central to the area being worked) facility
- containers are surveyed then covered with a tight fitting lid
- the exterior of the truck and container is washed
- the truck then hauls the material to the disposal facility.

4.1.2.2 Treatability Study. One excavation treatability study has recently been completed on a pluto crib site (116-F-4). Another excavation treatability study at the 118-B-1 burial ground is scheduled for the summer of 1994 (DOE-RL 1994e).

4.1.2.2.1 116-F-4 Pluto Crib Excavation. The purpose of the 116-F-4 excavation test was to provide design data, document the excavation costs, demonstrate the field analytical methods, and evaluate various dust control measures (DOE-RL 1994d). The test consisted of the following elements:

- preliminary site characterization and waste site location
- excavation of the waste site and associated contamination
- segregation and stockpiling of excavation spoil
- radiological screening, comparison of in situ measurements with laboratory analysis
- dust control measures in the area of excavation, on roadways, and on stockpiles
- site reclamation.

Workers planning and conducting the excavation were unable to locate construction records for the 116-F-4 pluto crib, as is common for many of the waste sites in the 100 Areas. One borehole was completed near the crib riser pipe as part of the LFI for the 100-FR-1 Operable Unit. A ground penetrating radar (GPR) survey and a cone penetrometer investigation were conducted to determine the location of the center of the crib, the limits of the crib structure and the limits of contamination. The GPR survey was largely unsuccessful due to the presence of fly ash on the surface. The cone penetrometer investigation consisted of pushing holes at 16 locations. The cone penetrometer was equipped with a sodium iodide gamma detector to provide gross gamma radiation measurements. The cone penetrometer was typically refused in the 2.1 to 3 m (7 to 10 ft) interval but proved to be an effective tool when penetration was possible. In the zone penetrated, the area of highest contamination was determined and the contaminant plume delineated laterally.

The excavation was performed using a CAT 245-B backhoe with a 3 yd^3 bucket attachment proceeding in 2-ft (0.6-m) excavation lifts. A 29 m by 29 m (95 ft by 95 ft) area was delineated at the surface to provide that a 1.5 horizontal to 1 vertical side slope for the planned 7.6-m (25-ft) depth of the excavation. Prior to each lift the excavated area was surveyed for radiation and the limit of the contaminated material delineated. Uncontaminated areas of the underlying lift were then excavated followed by the contaminated materials. Contaminated material was placed in an engineered onsite storage facility (Terra-stor). At the ninth lift radiation was just above spectral background limits in a small area near the vadose borehole location as measured by the in situ monitoring instruments. The remaining contaminated material was excavated with the backhoe. Excavation was initiated on September 20, 1993, and concluded on November 24, 1993. The typical work crew consisted of between 11 and 20 workers. The normal work schedule was from 0700 to 1600 hours 5 days per week. Approximately 5.25 productive hours were realized per day. A total of approximately 4500 yd^3 (3440 m^3) was removed, of which 500 yd^3 (382 m^3) was designated contaminated. Excavation rates varied from 30 to 90 yd^3/hr (23 to 68 m^3/hr) during the operation of the excavation equipment, excluding field screening durations (DOE-RL 1994d).

In situ radionuclide concentrations were measured through the use of a detection cart specially designed and constructed for in situ monitoring. The cart was equipped with five detectors; two thallium doped sodium iodide detectors, a hyperpure germanium detector, a prototype scintillation fiber optic beta detector, and a plastic scintillating beta detector. Samples were obtained for laboratory analysis for comparison purposes. Each lift was screened and sampled at 16 points forming a 6.1 m by 6.1 m (20 ft by 20 ft) grid. The cart was lowered into the excavation by crane and moved from point to point by hand or crane. Small volume soil samples were taken at three locations on each lift for comparison. The small volume samples only included sand, however, approximately 75% to 85% of the soil is cobble sized. As a result, a few 8 gallon samples were taken for segmented gamma scanning analysis. In situ measurements were adjusted for the weight percent of sand fraction in order to compare with the laboratory results from sand fraction analyses. Such corrections were only partially successful since contamination was fixed to the cobbles in different concentrations than on the sand. All measurement locations were also surveyed with standard health physics instrumentation (zinc sulfide scintillation and Geiger-Muller detectors). Work with the cart took from one to two days to complete per each lift. This was primarily due to the time required to process detector data. The in situ detection equipment were successful at the action levels used in delineating the extent of strontium-90 and cesium-137 within the 6.1 m by 6.1 m (20 ft by 20 ft) sampling grid.

In addition to radiological field screening, screening was also performed for chemical constituents. Four samples from lift five were screened for heavy metals and hexavalent chromium. A portable x-ray fluorescence analyzer was used to check for concentrations of heavy metals. A water extraction and calorimetric determination was used to screen for hexavalent chromium. No evidence of heavy metals or hexavalent chromium was found in any of the samples.

During the excavation four types of dust control tests were conducted; no control, control with water only, control with water and additives, and control with crusting agents. Two surfactants, MSDC and EMC^2, were selected for use as additives. Four crusting agents were selected; Road Oyl, Lignosite, Soil Seal, and XDCA. Low volume air samplers, personal air samplers, and real-time air monitors were used to help quantify dust generation. Evaluation of crusting agents were qualitative. Water was applied with hoses attached to a fire hydrant located nearby, mixtures were applied with the use of a fugitive dust control unit obtained from Idaho National Engineering Laboratory. A thermoplastic adjustable fog nozzle was preferred for most applications. Water spray alone controlled dust adequately. The maximum rate of application was 5,026 gal over a 3 hour period of heavy wind (17 to 30 mph). Lignosite was the best "all-purpose" crusting agent while Road Oyl was the best product for high traffic areas. The surfactants were not used frequently enough to adequately assess their performance (DOE-RL 1994d).

Site restoration activities were initiated upon completion of the test. These activities included surveying of the former location of the crib and final lift depth, backfill of the excavation to grade level, demobilizing equipment and supplies, and final cover installation on the Terra-stor. A 15 yd^3 (11.5 m^3) truck and a front end loader were used to place and compact fill in 18-in. lifts. A 10 yd^3 (7.6 m^3) truck assisted supplying material to the excavation for a portion of the duration. The average fill production rate was 210 yd^3 (160 m^3) per hour.

4.1.2.2.2 118-B-1 Burial Ground Excavation. A test excavation is planned for the 118-B-1 burial ground in August, 1994 (DOE-RL 1994e). The objectives of the test are to test different methods of excavation, test different methods of sorting materials excavated, and make observations concerning the types of wastes present.

Excavation will be conducted by both vertical (top down) and horizontal (from the side) methods and will be performed using a backhoe. The materials will be sorted using three different methods: using the backhoe itself to segregate different types of materials during excavation; using mechanical screening methods outside of the excavation; and using nonmechanical methods (manual sorting) outside of the excavation. In situ real time analytical field screening will be performed during the excavation and will be used to classify materials based on waste acceptance applicability criteria. Excavated materials will be stockpiled onsite then replaced at the completion of the work.

4.1.3 In Situ Containment

In situ waste containment actions consist of physical measures to restrict contaminant migration. Containment technologies include waste site isolation by a barrier and surface water management.

4.1.3.1 Barrier. A number of barrier types have been proposed for various applications at the Hanford Site. The two types which have been retained for this study are the Hanford Barrier and the Modified RCRA Barrier (RCRA Subtitle C design). The performance variations between the two types is summarized as follows:

- Hanford Barrier - design life of 1,000 yrs, maximum biointrusion (3 layer) protection, intended for transuranic (TRU) waste applications.

- Modified RCRA Barrier - design life of 500 yrs, less biointrusion (2 layer) protection, intended for non-TRU waste applications.

The following sections present the design and implementation of each of these barriers. A discussion then follows concerning the applicability of each type of barrier for the types of waste groups being evaluated.

4.1.3.1.1 The Hanford Barrier.

Description. The Hanford Barrier is a composite barrier system. Designs have been developed to meet the applicable RCRA regulations, site conditions, and expected waste (DOE-RL 1993f). The barrier is designed to meet the following criteria:

- prevent downward infiltration through the cover

- provide cover construction media which resist natural degradation processes

- provide a cover that requires no maintenance

- provide a functional life of 1,000 years

- prevent root penetration

- prevent animal and inadvertent human intrusion

- promote drainage and minimize erosion

- provide cover materials with a permeability less than or equal to any natural subsoils

- prevent the piping of fines into the lateral drainage layer.

The barrier is an experimental design, developed by the Hanford Site Permanent Isolation Barrier Development Program. A prototype has recently been completed at the 200-BP-1 Operable Unit.

The Hanford Barrier is a multi-layer system as shown in the cross-section in Figure 4-5. The major components of the system are as follows:

- The top layer 1.0 m (3 ft) consists of a silt loam and gravel admix. The second layer (1.0 m) consists of silt loam. These layers promote runoff, minimize infiltration, and provide near-surface storage capacity for infiltration so that it can be removed by evapotranspiration. Gravel in the top layer helps resist erosion. Silt provides a suitable medium for the growth of shallow-rooted vegetation.

- Layer 3 consists of a geotextile filter which aids in construction by preventing the mixing of the silt and sand layers. The geotextile filter is a fabric approximately 0.05 in thick, used to separate granular materials of different sizes and prevent mixing during construction. After completion of construction, this layer is non-functional.

- Layers 4 (0.15 m [0.5 ft]) and 5 (0.30 m [1 ft]) consist of sand and gravel respectively. The combination of these coarse layers beneath the fine layers (1 and 2) forms a capillary break, provided that unsaturated conditions are maintained. Water is then transported exclusively across this zone via vapor transport and infiltration is thereby minimized. The capillary break effect also inhibits biological activity. These layers also prevent the piping of soil into the underlying crushed basalt.

- Layer 6 (1.5 m [5 ft]) consists of crushed basalt having an average particle size of 0.1 m (4 in.). This layer is expected to deter deep rooted vegetation and burrowing animals from contact with the waste material.

- Layers 7 (0.30 m [1 ft]), 8 (0.15 m [0.5 ft]), and 9 (0.10 m [4 in.]) consist of drainage gravel, asphaltic concrete, and a base course, respectively. The asphalt layer contains twice the tar content of normal highway asphalt and is coated with a fluid-applied asphalt (styrene-butadiene). The increased tar content results in increased flexibility and decreased permeability. Any moisture which passes through the upper layers would be stopped by the asphalt and would drain laterally to the barrier edge. The asphalt also provides additional protection against biological intrusion (roots and burrowing animals). The base course provides a foundation for the asphalt layer. The base course is placed over a regraded and compacted soil foundation. Grading fill is added as necessary (Layer 10) to provide a 2% grade and facilitate construction of the superceeding lifts.

Construction of the barrier is performed according to the following general steps:

- The barrier system is designed to meet site-specific conditions. The design elements are presented in the previous section. The barrier design is modified per the specific waste site so that the performance applicability criteria are met. Such design modifications include the determination of the lateral limits of the barrier and require confident knowledge of the extent of contamination at each waste site. Barrier coverage must be demonstrated or otherwise verified through additional location investigations.

- Borrow sources for suitable materials are identified and materials tested to demonstrate suitability. Suitable silt-loam material has been identified from the former McGee Ranch, located northwest of the Yakima Barricade. Sources for the coarse fractions and grading fill are present in the area and suitable basalt quarry locations have also been identified onsite.

- Borrow materials are excavated and processed.

- Materials are transported to the construction site.

- Site security and support facilities are established.

- The foundation for the barrier is prepared. Such preparation includes clearing and grubbing (probably minimal), grading (with fill only), and control of surface drainage. Stabilization and compaction of the subgrade are optional but recommended to reduce the potential for differential settlement and subsequent failure of the barrier. Such compaction may incorporate the use of in situ stabilization technologies such as grouting and dynamic compaction (discussed as separate technologies).

- Preparation of the subgrade will require the removal of structures which inhibit proper placement of the barrier such as retention basins and outfall structures. Generally no soil is removed from the site, to avoid any disturbance or need for disposal. Preparation of the site is accomplished entirely with fill.

- The barrier construction is initiated. The construction of each layer is sequenced so each layer is completed prior to the construction of the above layer. Layers are constructed by spreading the material in lifts, smoothing the material to a uniform thickness, final adjustment of material moisture content, and compaction of the lift. Each lift is subjected to construction quality assurance testing and final adjustments.

- Access for possible instrumentation to monitor leachate and/or groundwater is installed during construction of the barrier to avoid later disturbance.

- Final runon and runoff elements (such as armored channels) are installed and final site grading performed.

- The finished barrier is revegetated with appropriate native vegetation or seeds.

The procedure for construction could vary with respect to the various waste groups. Construction over retention basin sites would require the removal of any remaining above ground structures, and backfilling to provide a substrate with positive drainage. Burial ground sites may require efforts to compact or stabilize the substrate to avoid future subsidence.

The equipment needed to construct the Hanford Barrier is readily available construction equipment including excavators, earth movers (dozers, front end loaders, scrapers, graders and hauling/dump trucks), compactors (sheepsfoot rollers, smooth wheeled rollers, vibratory drum rollers, rubber tire loaders, and power tampers), and other specialty equipment such as an asphalt paving machine. The specific equipment used will vary based on the materials being placed in each layer of the barrier.

Based on performance of similar types of barriers and modeling results, the Hanford Barrier may provide an effective means of inhibiting the migration of contaminated materials present at the waste site. However, final site-specific design will require that additional investigation be performed to adequately locate and delineate the extent of contamination. The applicability criteria used for selecting the Hanford Barrier as the cover to be implemented for an IRM, and a brief discussion of the application of this applicability criteria for the 100 Areas, are as follows (DOE-RL 1993f):

- Characterization data qualifies the waste site as a TRU contaminated site. Based on process knowledge and existing site data the waste sites in the 100 Area are not classified as a TRU site (WHC 1991b).

- The waste site is immediately adjacent to a TRU contaminated site. Based on process knowledge and existing site data, the waste sites in the 100 Area are not classified as a TRU site.

- Waste sites which have been determined to require a greater degree of protection than that afforded by a less protective design. The sites in the 100 Areas do not require this higher degree of protection based on process knowledge and existing site data.

Generally, these applicability criteria do not apply to any of the waste site types in the scope of this study. Therefore the Hanford Barrier will not be applied at any of the sites unless such protection is warranted for a specific site.

Treatability Study. A prototype of the Hanford Barrier has recently been constructed at the 200-BP-1 Operable Unit. The prototype study is conducted in two phases. Phase I concentrates on the design and construction of the barrier. The construction includes the installation of a leachate monitoring system. Phase II involves a 3-year testing and monitoring program.

The prototype barrier has been constructed over the 216-B-57 crib. The crib consists of a 0.3 m (12-in.) corrugated and perforated steel pipe within a 61-m (200-ft) long, 4.6 m (15-ft) wide gravel infiltration bed. The site received storage condensate waste from the 241-BY tank farm. Potential contaminants of concern include cadmium, nickel, polychlorinated biphenyls, total uranium, cobalt-60, strontium-90, technetium-99, cesium-137, radium-226, and plutonium-238/239. The majority of the contaminants are located at a depth of 4.6 to 9.2 m (15 to 30 ft) below ground surface. Groundwater is at a depth of approximately 70.1 m (230 ft) below ground surface. The topography at the site is such that ground water and surface water flow from south to north.

The barrier section has been constructed as previously described. Laterally, as measured along the asphalt layer, the barrier extends approximately 100 ft (30.2 m) east, south, and west and 13.7 m (45 ft) north of the limits of the waste site. The fully functioning dimensions of the barrier measure 32 m by 69 m (105 ft by 226 ft). These limits were established to provide cover for the infiltrative surface of the crib plus the near surface plume extension at the south end of the crib. To test the behavior of different slope materials, the basalt layer is expanded and daylights along the eastern edge of the barrier structure.

The monitoring program will measure moisture within the barrier, infiltration, and site-specific hydrologic conditions. Three types of moisture measurement devices are being constructed within the barrier; a pan lysimeter, neutron probe access, and a water collection system. The pan lysimeter will be constructed under the asphalt concrete layer in both the barrier and the test pad, and used to detect and collect moisture that penetrates the asphalt. Neutron probe access tubes are installed in the lower silt layer and below the asphalt concrete layer and will allow moisture measurement in those zones. A water collection system will be installed on top of the asphalt concrete layer in order to pipe the moisture to siphon vaults, and to measure the flow from each of the 13 collection zones.

4.1.3.1.2 The Modified RCRA Barrier (RCRA Subtitle C Design).

Description. The Modified RCRA Barrier is a composite barrier system designed to meet the minimum technology requirements contained in 40 CFR 264.301. Three Modified RCRA Barriers have been designed at the Hanford Site; the PUREX cover, the 183-H cover, and the Hanford Nonradiological Dangerous Waste Landfill (NRDWL) cover. The NRDWL cover design has also been modified to make it suitable for use at low level radionuclide waste sites making it the most suitable barrier for use in the 100 Areas. The designs have been developed to meet the applicable RCRA regulations, site conditions, and expected waste.

The barrier is designed to meet the following criteria:

- prevent downward infiltration through the cover
- provide cover construction media which resist natural degradation processes
- provide a cover that requires no maintenance

- provide a functional life of 500 years
- prevent root penetration
- prevent animal and inadvertent human intrusion
- promote drainage and minimize erosion
- provide cover materials that have a permeability less than or equal to any natural subsoils
- prevent the piping of fines into the lateral drainage layer.

The RCRA barrier is a proven technology and similar designs have been implemented at numerous other hazardous waste sites, however, the modifications for Hanford applications make the design experimental since no such barrier has been constructed.

The Modified RCRA Barrier is a multi-layer system as shown in the cross-section in Figure 4-6. A permit application was submitted for the NRDWL cover in 1990. Three modifications which have been made to the NRDWL design are; an increase in thickness of the top soil layer, addition of gravel to the top soil layer, replacement of the geonet and high-density polyethylene (HDPE) liner with a sand filter and an asphalt liner. The major components of the system are as follows:

- The top (0.5 m [1.6 ft]) and second (0.5 m [1.6 ft]) layers are similar to the Hanford Barrier.
- Layers 3 (0.15 m [0.5 ft]) and 4 (0.15 m [0.5 ft]) are similar to layers 4 and 5 of the Hanford Barrier.
- Layers 5 (0.30 m [1 ft]), 6 (0.15 m [0.5 ft]), and 7 (0.10 m [4 in.]) consist of drainage gravel, asphaltic concrete, and a base course, respectively. The asphalt layer is coated with a fluid-applied asphalt (styrene-butadiene). Any moisture which passes through the upper layers would be stopped by the asphalt and would drain laterally to the barrier edge. The asphalt is expected to prevent biological intrusion (roots and burrowing animals). The base course provides a foundation for the asphalt layer. The base course is placed over a regraded and compacted soil foundation. In a typical RCRA design a HDPE liner over recompacted clay is used in place of the asphaltic layer. The modification has been made to use asphalt since the performance of synthetic liners over long periods of time is unknown, liners are subject to tearing under the stresses induced by ground movement, and clay is subject to desiccation in the arid climate of Hanford. Grading fill is added as necessary (Layer 8) to provide a 2% grade and facilitate construction of the superceeding lifts.

The general construction methodology and equipment used is similar to that used to construct the Hanford Barrier.

Based on performance of similar types of barriers and modeling results, the Modified RCRA Barrier may provide an effective means of inhibiting the migration of contaminated materials present at a waste site. However, final site-specific design will require that additional investigation be performed to adequately located and delineate the extent of contamination. The criteria used for selecting the Modified RCRA Barrier as the cover to be implemented for an IRM are as follows (DOE-RL 1993f):

- Characterization data qualifies the waste site containing hazardous or radioactive constituents above threshold values (PRG).
- The risk assessment/performance assessment indicates that the contaminants are mobile and at sufficient concentration to require a hydrologic barrier.

Generally, these applicability criteria apply to all of the waste site types in the scope of this study. Therefore, the Modified RCRA Barrier will be considered for use in all containment type alternatives. If additional protection is warranted for a specific site, the Hanford Barrier may be considered.

4.1.3.2 Surface Water Management. Surface water management consists of measures to control the runon and runoff of surface water to and from a waste site. Elimination of runon to a waste site reduces the potential for infiltration through contaminated materials and spread of contaminants. Collection of waste site runoff reduces the spread of contamination via water which has contacted contaminated materials. Surface water management may not comprise a remediation technology in itself but is a necessary addition to many of the remedial alternatives.

Surface water runon can be controlled by constructing drainage channels, culverts, and detention ponds. Control can also be attained by providing positive relief by redirecting the surface water in the area to be protected. Runoff of surface water which has been in contact with contaminated materials must be collected, held in detention ponds, tested, treated (if necessary), and released. Potential for runoff also exists during transportation. This potential can be eliminated through the use of covers for the transport containers.

In the 100 Areas, surface soils are typically very permeable, precipitation tends to infiltrate quickly, and little runoff occurs. None of the waste sites being evaluated are in areas susceptible to inundation or erosion during high precipitation events (Gee 1987).

4.1.4 In Situ Treatment

In situ treatment actions include grout injection, dynamic compaction, and in situ vitrification (ISV).

4.1.4.1 Grout Injection. Grouting is often used in construction projects to increase shear strength, densify, and decrease the permeability of soil and rock. Grouting is gaining acceptance for the solidification of buried wastes and as a preconstruction procedure to eliminate problems that otherwise might occur during the construction phase. Two specific types of grout injection are considered for use in remedial alternatives; void grouting and vibration-aided grout injection. Void grouting is considered for filling large voids, specifically the effluent pipelines. Vibration-aided grout injection is considered for solidification and stabilization of buried solid wastes.

4.1.4.1.1 Void Grouting. When filling large void spaces with grout a number of factors must be considered including: fluidity of the grout, curing time, shrink resistance, control of cracking, compatibility with materials in void and walls of void, cured permeability, and cured strength. These properties can be controlled through the proper mixture of cement, aggregate, and additives.

Void grouting is generally performed with sand-cement based grouts injected at low pressures (Navy 1983). Typical sand-cement ratios vary from about 2:1 to 10:1 (loose volume). Addition of bentonite or fly ash reduces segregation and increases pumpability. Portland Type I cement is sufficient unless special resistance or strength properties are required. Type IV cement provides superior curing properties for massive structures. Substitution of pozzolan for cement increases shrink resistance but decreases strength. Water-cement ratios vary from about 2:1 to 5:1 by volume. Final compressive strengths vary from 100 to 700 psi. The appropriate grout mix design should be developed for the types of voids to be filled.

Selection of the proper grout mixing and placement system depends on the size of the grouting project. For small rates of placement, grout can be mixed in batches. For larger rates of application a mobile continuous mixer is preferable. Sand-cement grout is typically placed using conventional long stroke slush pumps with large valve openings.

The effluent pipelines will require large volumes of grout. The pipelines can be accessed from junction boxes and grouting can progress beginning with the box lowest in elevation and ending with the highest box. The lines are adequately sloped enabling the grout to flow down and completely fill the void space.

4.1.4.1.2 Vibration-Aided Grout Injection. Vibration-aided grout injection is an in situ stabilization/solidification technique involving the injection of cement grout into a contaminated zone with simultaneous vibration of the materials within the zone. The technology is a combination of vibro-densification and pressure grouting, two well developed stabilization technologies. Vibration provides a nonintrusive means for mixing the materials in the zone of interest with the grout. Successful completion provides encapsulation of waste into a monolithic block which resists leaching or migration of contaminants.

Vibration-aided grout injection is not a commonly applied technology for in situ treatment of waste materials. However, similar equipment and technology is typically applied in the construction of vibrated beam slurry cutoff walls. The vibrated beam involves the use of a crane operated vibrating driver and extractor unit which both drives and extracts a wide flange structural beam. Attached to the beam are grout pipes for injection of a cement bentonite backfill. In the construction of cutoff walls the beam is vibrated into the ground and a low permeability cement mixture injected under pressure into the resulting void when the beam is withdrawn. For enhanced migration the cement mixture can be thinned and vibration maintained during grouting. For vibro-densification, probes are typically placed at 1 to 3 m (3 to 10 ft) intervals. The vibratory hammer operates at 25 Hertz with vibrations of 1 to 2.5 cm (3/8 to 1 in.) of amplitude (vertical) (Navy 1983). Grout is injected until refusal pressures are attained (approximately 1 psi per foot of depth at the injection point) or grout returns to the surface. In heterogeneous buried waste the degree of mixing with the grout may be difficult to control and the grout will generally follow preferential flow pathways. In addition, if not penetrated by the beam, sealed void spaces, such as closed containers or metal boxes, may not be grouted.

In situ grouting for stabilization requires a comprehensive characterization of the waste matrix prior to undertaking the process to identify contaminants which may interfere with group curing and to determine the number of injection points. The specific grout mixture cannot be specified without site-specific studies, typically chemical type grouts are best suited for fine-grained materials with small pores and cement grouts are best for coarse-grained materials. A combination of grouts may also be used.

In situ grouting can be an effective means of immobilizing and stabilizing contaminated materials present at waste sites. However, the grouting process, especially for complex subsurface geometries (such as burial grounds), is difficult to assess during implementation. This effectiveness can be difficult to verify and may require post implementation intrusive investigation. Long term effectiveness in immobilizing radionuclides depends on the ability of the grouted mass to resist degradation. Final site-specific design of the grouting program will require that additional characterization be performed to adequately locate and delineate the extent of contamination. No opportunity exists to follow an observational approach in delineating contamination extent, as in other methods of remediation such as excavation. The technology is implementable through the use of equipment which has been developed for the method. Site-specific studies will need to be performed to select the proper injection grout mixture(s) and determine appropriate locations of injection points. Used in the correct manner, in situ grouting action can reduce exposure risk at the site by reducing the potential for settlement and immobilizing waste through encapsulation. Grouting of buried mixed waste at the DOE's Savannah River site was rejected as a remedial technology (Bullington and Frye-O'Bryant 1993). Evaluations concluded that grouting would not fill enough voids without creating uncontrolled surface cracking and surface releases of grout contaminated with hazardous and radioactive constituents. Site-specific characterization in the 100 Areas should be accomplished prior to implementation, and treatability studies may be required to adequately assess the applicability of in situ grouting at the Hanford Site.

4.1.4.2 Dynamic Compaction.

4.1.4.2.1 Description. Dynamic compaction is a technique for in situ consolidation of soils and buried wastes. The process involves dropping a weight (tamper) from a predetermined height onto the area to be compacted. The high energy imparted to the soil causes deep densification. The method has been used for about 20 years to compact foundations for buildings, highways, and airfields. The method has also seen limited application in the hazardous waste industry. Successful completion of dynamic compaction reduces the pore spaces, minimizes groundwater contact, and minimizes potential subsidence for a subsequent barrier. The performance of compacted material, in regard to moisture migration potential, is a direct function of the void ratio after compaction, which is in itself, a function of soil particle size distribution.

Specific procedures to be followed have been established. Spacial distribution and the time sequence of dropping the weights are critical. Additional factors such as effects on nearby structures, soil and waste conditions, and characteristics of transmitting impact and vibration energy must be considered. The cumulative applied energies of the process typically range from 30 to 150 ft-ton/ft^2 and may succeed in densifying soil or waste to a depth of 15.2 m (50 ft).

The effectiveness of the technique is assessed by measuring the volume and area of the craters created by dropping the weights in a pre-planned sequence. The data can be used to calculate the increase in density and depth of influence. Evaluation can also be supported with standard penetration tests, cone penetration tests, or geophysical approaches.

The equipment required consists primarily of a steel or concrete tamper suspended from a crane. Tampers vary in weight from 5 to 20 tons and drop heights range up to 30.5 m (100 ft). The most efficient tamper weight and drop height can be determined in a site-specific test program.

4.1.4.2.2 Similar Site. The Mixed Waste Management Facility (MWMF) at the DOE's Savannah River site was recently remediated using dynamic compaction and closed under RCRA (Bullington and Fry-O'bryant 1993). The MWMF site consists of a 58 acre burial ground for low level radioactive waste. Low-level waste was buried in engineered trenches designed to accept only metal boxes (designated B-25 boxes), and 55 gallon drums. Boxes were stacked no more than four high, drums were placed between the boxes and the sloped walls of the trench. The filled trenches were covered with a minimum of 1.2 m (4 ft) of overburden. Closure consisted of dynamically compacting the waste trenches, then placing a 1-m (3-ft) kaolin barrier followed by a 0.6-m (2-ft) final vegetative layer over the area.

During feasibility evaluations conducted prior to closure, settlement of the trenches was expected to occur due to buckling of the B-25 boxes under the weight of the RCRA closure barrier. Various methods of inducing settlement were considered including static surcharging, dynamic compaction, and grouting. Construction of bridging covers were also considered. Dynamic compaction and surcharging were determined to be the most effective and practical methods for reducing further settlement. Test programs of both methods demonstrated that dynamic compaction was more effective. The dynamic compaction test showed that the crater depth for a given number of drops increased with the total energy of the drop rather than the energy per imprint area. A 20-ton weight was selected at a drop height of 12.8 m (42 ft).

The following general procedure was followed at the Savannah River site:

- Lampson LDC-350 cranes were obtained and modified specifically for dynamic compaction. The usual two-line hoist was replaced with a single-line hoist to minimize friction losses. A 20 ton tamper, 2.4 m (8 ft) in diameter, was selected for use.

- The soil cover over the burial ground is increased to a total thickness of 1.8 m (6 ft) allowing a maximum crater depth of 1.8 m (6 ft) to be obtained without exposing buried wastes.

- The surface of each burial trench, typically 6.1 m (20 ft) wide and 6.1 m (20 ft) deep, were subdivided into 3m by 3 m (10 ft by 10 ft) grid.

- Initially, specifications called for a maximum of 20 drops, from a height of 12.8 m (42 ft), per grid point or until the maximum crater depth of 1.8 m (6 ft) was reached. Later a drop height test program was conducted and the drop height increased to 21-24 m (70-80 ft).

- The tamping pattern consisted of primary drop points following a zig-zag pattern along the grid followed by secondary drop points filling in the remaining grid nodes (Figure 4-7).

- An average of about 13 drops were required at each point to obtain an average crater depth of 1.7 m (5.56 ft).

- Resultant craters were backfilled and compacted using the tamper and a 12.8 m (42 ft) drop height.

Closure of additional trenches adjacent to the MWMF have been conducted since the completion of the MWMF closure (Billington and Fry-O'bryant 1993). To perform these closures additional studies were conducted to address concerns of vibrational damage to the existing barrier, other waste disposal facilities and utilities. These studies concluded that dynamic compaction should not be performed within 15.2 m (50 ft) of the existing barrier. During field testing the applicability criteria for discontinuation of compaction was changed from a the previously used maximum depth to an incremental depth (6 cm [0.2 ft] for two consecutive drops).

4.1.4.3 In Situ Vitrification.

4.1.4.3.1 Description. In situ vitrification is a thermal treatment process that converts soil and other materials into stable glass or glass-like crystalline substances. In situ vitrification utilizes the principle of joule heating to transmit an electric energy to the soil heating it and producing a molten glass zone that stabilizes the contaminants in place. In situ vitrification produces an extremely durable product that is capable of long-term immobilization of many metals and radioactive wastes.

In the ISV process, electrodes are inserted into the soil and a conductive mixture of flaked graphite and glass frit is usually placed between the electrodes to act as the starter path for the electrical circuit. The current of electricity passing through the electrodes, heats the soils and graphite to temperatures of approximately 2,000°C (3,632°F), thus melting the soil. The graphite starter path is eventually consumed by oxidation, and the current is transferred to the molten soil (now electrically conductive). As the vitrified zone grows downward and outward, metals and radionuclides are incorporated into the melt. Convective currents within the melt mix materials that are present in the soil. Organics are vaporized and then pyrolyzed as they pass upward through the melt. When the electrical current ceases, the molten volume cools and solidifies. A hood placed over the processing area provides confinement for the evolved gases, drawing the gases into an offgas treatment system.

The ISV treatment system consists of the electrical power supply, the offgas hood, an offgas treatment system, a glycol cooling system, a process control station, and offgas support equipment (Freeman 1989). The offgas system consists of a gas cooler, two quench towers, hydrosonic tandem nozzle scrubbers, two heat exchangers, three vane-separated mist eliminators, two scrub solution tanks, two pumps, a condenser, a greater, and high-efficiency particulate air filters (PNL 1992). With the exception of the offgas hood, all process components are contained in three transportable trailers.

In situ vitrification, although still innovative, has proven to be an effective remedial technology for the immobilization of inorganics, the application to a wide variety of contaminants (such as organics, metals, and radionuclides), volume reduction, as well as protection of the public and workers by avoiding excavation, material handling, and disposal (EPA 1992). However, specific site characteristics must be considered in determining the implementability of ISV. The presence of excessive moisture or groundwater can limit the economic practicality of ISV due to the time and energy required to drive off the water. Soils with low alkaline content may be unable to effectively carry a charge and thereby diminish the applicability of ISV (EPA 1992). Large quantities of combustible liquids or solids may increase the gas production rate beyond the capacity of the offgas system. In addition, the presence of metals in the soil can result in a conductive path that would lead to electrical shorting between electrodes. However, this problem may be avoided by innovative electrode feeding techniques. In situ vitrification is currently limited to a maximum depth of 5.8 m (19 ft) (EPA 1992).

Prior to implementation of ISV, location verification and site preparation must occur. Site preparation includes clearing vegetation, grading, and removal of uncontaminated overburden by excavation (cost to excavate uncontaminated material is much lower than the cost to vitrify). The waste area will be divided into vitrification settings based on an electrode spacing of 4.5 m (14.8 ft). Four electrodes will be utilized at a time, at a width of 7.8 m (25.6 ft) per setting. Therefore, approximately one setting will be needed per 56 m^2 of waste area. After the system has been staged, the four electrodes will be simultaneously fed into the soil initiating the melt. The electrodes will be continually fed until the desired vitrification depth is achieved and the melt is completed. An ISV processing rate of approximately 4 to 5 tons/hour is anticipated (EPA 1992). Once solidified, the sunken vitrified area will be backfilled to a minimum of 1 m (3 ft) above the block. A crane will be used to transport the electrode frame and hood to the next setting.

4.1.4.3.2 Treatability Study. Two ISV treatability studies were conducted at the Hanford Site between 1987 and 1989 to evaluate ISV under site-specific conditions. Two waste cribs (216-Z-12 and 116-B-6A) were vitrified to depths of 4.9 and 4.3 m (16 and 14 ft), respectively. The depth limitation at the 116-B-6A crib area was believed to be the result of a cobble layer present at 4.3 m. This resulted in preferential lateral growth rather than downward growth. When a large particle size layer is encountered, a high equilibrium temperature is necessary to achieve the same downward progression rate (PNL 1992). However, typically, heterogenous power distributions occur within the melt: half of the delivered power is held in the upper third of the melt, and power decreases as depth increases. This results in a slower melt advance as the melt reaches an equilibrium and finally melt advance stops (EPA 1992). Thus, the melt at the 116-B-6A crib may not have extended much deeper, regardless of the cobble layer.

Although treatability studies have demonstrated possible effectiveness problems due to depth limitations, the Hanford 100 Areas includes locations where ISV may be implementable. In situ vitrification can be considered effective for the stabilization of radionuclide and metals contaminated soils if the contaminant material type, concentrations, and depth are within process parameter limitations. Equipment has been developed to implement the process although it is not considered readily available nor is the technology commonly applied.

4.1.5 Ex Situ Treatment and Processing

Ex situ treatment technologies provide treatment following removal. Technologies examined include thermal desorption, cement stabilization, vitrification, soil washing, and compaction.

4.1.5.1 Thermal Desorption. Thermal desorption is a process that uses indirect heat to thermally remove VOC and some semivolatile organic compounds (SVOC) from contaminated soils, sediments, solids, or sludges at low temperatures. The process does not use incineration or pyrolysis to treat the contaminants, but rather volatilizes the organics, leaving the processed solids virtually free of organic contaminants.

A thermal desorption system typically consists of a rotary kiln with two concentric shells. The inside shell, or processor, is sealed and houses the contaminated material. The annular space between the two shells houses burners that indirectly heat the contents of the processor while kiln rotation allows for constant mixing and exposure for heat transfer. Depending on the design, the contaminated soils are heated to between 232 and 593°C (450 and 1,100°F) at residence times ranging from 60 to 300 minutes (Sudnick 1993 and Krukowski 1992). An inert carrier gas is sometimes used to remove and direct the VOC and particulates from the processor to the gas treatment system. The treatment system typically consists of heat exchangers and scrubbers that cool the process stream for the removal of VOC and particulates. The remaining vapor stream is passed through an abatement system to ensure regulatory compliance prior to atmospheric release. The majority of the treated vapor stream is preheated and recirculated back through the annular space between the shells for re-use in the desorption process.

Thermal desorption is a process that has been proven effective in removing VOC and some SVOC from soils and solids using heat. The process can be more economical than other thermal processes such as incineration or pyrolysis due to the energy savings incurred by the lower operating temperatures. Some factors that may influence operating efficiencies and costs include waste type, contaminant type, soil moisture content, particle size, and treatment goals.

Contaminant removal efficiencies vary with each compound and can affect treatment goals. Thermal desorption may not be effective in treating soils or solids contaminated with high boiling point SVOC. Fortunately, the SVOC that have been detected in soils and sediments at the Hanford 100 Areas have boiling points that lie within the operating temperature ranges previously discussed.

Soil moisture content is another variable that can drastically affect efficiency and cost. Most thermal desorption units operate economically at a soil moisture content of 20%. Soil containing moisture exceeding this value may require pre-drying or dewatering, resulting in increased costs.

Thermal desorption may be an effective process to treat the limited VOC and SVOC contamination in soils at the Hanford 100 Areas. A variety of full-scale systems are readily available and could be easily implemented at any of the sites. However, a thermal desorption treatability study to support remedy design should be performed prior to full-scale operation (DOE-RL 1992b). The treatability study should incorporate an evaluation of various co-contaminants on the thermal desorption process.

4.1.5.2 Cement Stabilization.

4.1.5.2.1 Description. Cement stabilization involves mixing contaminated material with cement to reduce leachability and bioavailability. The cement mixture typically consists of pozzolanic agents such as fly ash or kiln dust, and cement. Plasticizers, hardening agents, and other additives are available to adjust the required physical properties of the final product. The contaminants do not interact chemically with the solidification agents but are mechanically bonded (i.e., encapsulated). Treated waste exists as a solidified mass similar to concrete with significant unconfined compressive strength.

Cement stabilization is an established technology for treatment of wastes and soils contaminated with inorganic compounds and radionuclides. A typical cement stabilization process will involve the following steps:

- contaminated materials are screened to remove oversized material
- materials are introduced to a batch mixer and mixed with water, chemical reagents and additives, and cement
- after the material is thoroughly mixed it is discharged into molds and allowed to solidify

- the solidified unit is then disposed (Environmental Restoration Disposal Facility [ERDF] or W-025).

A variety of mixing systems are available and are generally of two types, mobile plants and modular plants. The system will include a silo for cement storage, a weight batcher for control of the cement feed, and a ribbon blender for mixing. Excavation equipment is used for loading the material to be solidified into the unit. A modular mixing plant can produce approximately 180 yd^3 (137 m^3) of solidified waste per day (EPA 1986).

Cement solidification is an effective means of immobilizing contaminants in materials excavated from waste sites. The technology is most applicable for materials with inorganic contamination. Verification of effectiveness typically requires sampling and testing of the end product. The technology is well established and is implementable through the use of equipment which has been developed for the method. Site-specific studies will need to be performed to modify the equipment used and evaluate specific cementing agents. No specific ARAR exist to prohibit this action. Cement stabilization reduces exposure risk through immobilization, however the end product must be disposed of.

4.1.5.2.2 Treatability Study. Two treatability studies may provide supporting information for applications at the Hanford Site - a study completed at Fernald and a study planned at Hanford.

Fernald Study. A cement solidification/stabilization treatability study was recently completed for operable unit 1 of the Fernald Environmental Management Project (DOE 1993). Cement solidification testing was performed on waste from six waste pits. The waste treated was derived from Waste Pits 1, 2, 3, 4, 5, and 6. The waste composition is as follows:

Waste Pit 1: Received filter cakes, vacuum-filtered sludges, magnesium fluoride slag, scrap graphite, and contaminated brick. Contains 1,075 metric tons (MT) of uranium.

Waste Pit 2: Same as Waste Pit 1. Also received raffinate residues. Contains 175 MT of uranium.

Waste Pit 3: Received lime-neutralized raffinate slurries, contaminated storm water, vacuum-filtered production sludge, neutralized liquid from process systems, neutralized refinery sludges, and cooling water from heat treatment operations. Contains 846 MT of uranium and 97 MT of thorium.

Waste Pit 4: Received solid wastes including process residues, scrap uranium metal, off-specification intermediate uranium products and residues, thorium metal and residues, barium chloride and contaminated ceramics. Also received noncombustible trash including cans, concrete, asbestos, and construction rubble. Lime was occasionally added for uranium precipitation. Contains 2,203 MT of uranium and 74 MT of thorium.

Waste Pit 5: Received slurries including neutralized raffinates, acid leachate, filtrate from sump slurries, lime sludge, thorium in barium carbonate sludge, thorium in aluminum sulfate sludge, and uranium in calcium oxide sludge. Contains 527 MT of uranium and 72 MT of thorium.

Waste Pit 6: Received magnesium fluoride slag, process residues, filter cakes, extrusion residue, and heat treatment quench water. Contains 1432 MT of uranium.

Portland cement (Type I/II) and blast furnace slag (BFS) were used as binders. Additives included Type F fly ash, site fly ash, absorbents, and sodium silicate. Solidified samples were tested for strength, leach resistance, permeability, and durability. The following results were obtained:

- All formulations passed toxicity characteristic regulatory applicability criteria in the toxicity characteristic leaching procedure (TCLP) leachate.
- Leachability of uranium was controlled except when present in high concentrations (Waste Pit 4).
- No significant temperature increases or offgassing occurred during mixing.
- Formulations developed could be applied at a large scale.
- Formulations with >43% portland cement Type II were effective in meeting the 500 psi strength requirement set for an onsite retrievable waste form. This composition also effectively controlled leaching of uranium and gross alpha and beta.
- A significant increase in volume results from the cement stabilization process.
- Raffinate residues or lesser amounts of uranium (90% less than Pit 1) in Pit 2 drive the percentage of organics in the waste to a much higher level.
- Permeabilities of all the solidified samples were low.
- Solidified samples passed applicability criteria set for durability (wet/dry and freeze/thaw). Addition of BFS reduced durability.

Hanford Study. A Hanford Site cement solidification treatability study is scheduled to be conducted during the period from June to December 1994 (DOE-RL 1994f). The study is designed to identify potential cement-based solidification mixtures that result in the beneficial use of soil washing fines. It is anticipated that the major contaminations will include europium, cobalt-60, and cesium-137. Formulations will be developed using Portland cement as the primary solidification agent. Portland cement Type I/II and Type F will be considered. Site fly ash, obtained from the active pile at the 200 East Area power house, will be added to increase the strength of the treated waste and decrease the effect of inhibitors such as sulfate and oil. Silica fume will also be considered to increase the bearing strength and decrease the porosity of the cured material. Silica fume will accelerate the rate of set, react with metals and decrease their solubilities and minimize the effect of inhibitors. Plasticizers or superplasticizers will be considered to increase the workability of the mixes. Calcium chloride will be considered as an accelerator. Additional reagents such as adsorbents (attapulgite and clinoptilolite) and BFS may be added to reduce leachability, increase bearing strength, decrease porosity, modify oxidation potential and minimize the effect of inhibitors.

A series of tests will be performed to evaluate the properties of the mix and cured material. Measurements will include flowability, time to set, heat generation, bulking, leachability (model toxicity characteristic leaching procedure and TCLP), permeability, shrinkage, bleed, freeze/thaw and wet/dry durability, shear strength (torvane), and penetration resistance. The study will also identify potential applications for codisposal.

4.1.5.3 Soil Washing.

4.1.5.3.1 Description. Soil washing is a remedial technology that may result in the removal of organic compounds, inorganic compounds, and radionuclides from soils. Soil washing can consist of size separation of highly contaminated soil fractions (usually fines) from minimally contaminated soil fractions (typically course gravels and sands), mechanical abrasion (such as trommels, ball mills or autogenous grinding) to remove surface contamination, or solvent extraction to chemically leach the contaminants from the soil particles.

Soil washing using physical separation is performed when contaminants are concentrated in one soil size fraction. This typically occurs with the finer soil fractions due to the greater surface area per unit mass and thus greater adsorption tendencies. The purpose of physical soil separation is to segregate the contaminated fractions from the relatively clean soil, thus reducing the volume of contaminated soil for disposal. Physical separation can involve wet or dry sieving alone or in combination with gravity separation, classification, attrition scrubbing or autogenous grinding, followed by some form of waste water treatment involving suspended solids recovery. Attrition scrubbing is performed to separate by friction, contaminants that exist as coatings or precipitates on fine soil particles. Autogenous grinding performs the same function on coarse soil particles. Physical separation is most effective when the majority of contaminants are concentrated on one soil size fraction and the contaminated soil fraction is a minor portion of the soil mass. Soil washing by physical separation can also be performed as a preliminary step in soil washing by solvent extraction.

Soil washing by solvent extraction involves the selective removal of contaminants from soil particles by contact with a liquid. This process has been used extensively in the mining and metallurgy industries, and the same basic principles apply to the extraction of contaminants from soil. The success of this technique generally lies in the proper selection of extractants (chemicals) and in understanding the kinetics of the reactions of concern (DOE-RL 1993g). Typical extractants include aqueous acids, alkalis, organic solvents, and surfactants. Extraction solvents are not currently available for all contaminants, and extraction efficiencies may vary for different types of soils, concentrations of contaminants, and site-specific parameters (Freeman 1989). Solvent extraction usually involves mixing the soil and solvent in an extraction tank for a period of time that allows intimate contact to occur. The suspended soil particles are allowed to settle by gravity for collection. The solvent mixture is decanted and the fine particles are separated usually by centrifugal action. Two bench-scale treatability studies have been conducted on 100 Area soils in support of soil washing technologies. These studies are presented in Sections 4.1.5.3.2 and 4.1.5.3.3. In summary, the soil washing treatability studies indicated that soil washing can be effective on the 100 Areas soils to some extent. As expected, soil samples indicated that the contaminants were present primarily on fines in certain areas. However, a large mass of cobbles and gravels were also affected by radionuclide contamination. The bench-scale studies provided insufficient data to recommend autogenous grinding or chemical extraction on a full-scale basis. A field-scale treatability test for autogenous grinding and chemical extraction needs to be performed to consider these technologies along with a soil washing alternative. Therefore, physical separation and attrition scrubbing only will be evaluated at this time as part of a soil washing alternative for the 100 Area soils.

A field-scale treatability study for soil washing is planned for the 100 Areas. Upon its completion, this technology evaluation may be changed to incorporate the findings of the study.

4.1.5.3.2 100 D and 100 B/C Area Treatability Study. A bench-scale soil washing treatability study was conducted using soils from two 100 Area trenches (116-D-1A and 116-C-1). The objective of the study was to evaluate the use of physical separation systems and chemical extraction methods as a means of separating chemically and radioactively-contaminated soil fractions from uncontaminated soil fractions (DOE-RL 1993g).

Prior to soil washing, soil samples were collected so that the physical, chemical, and mineralogical characteristics of the soil could be determined. Moisture content analysis indicated low contents of clays and organic matter in the 100 Area soils. Particle size distributions confirmed the results of the moisture analysis. Coarse sands and gravels account for approximately 97% of the total mass of samples obtained from trench 116-C-1, and for approximately 50% of the total mass of samples obtained from trench 116-D-1B. Chemical characterization tests showed low total organic carbon values, slightly alkaline soils, and calcium as the dominant exchangeable cation indicating the ability to flocculate during washing (DOE-RL 1993g). All samples included cobalt-60, cesium-137 and europium-152. Maximum activities in the 116-C-1 trench occurred in the >2-mm fraction at levels of 525, 5,495, and 2,320 pCi/g for cobalt-60, cesium-137 and europium-152, respectively. Maximum activities in the 116-D-1B trench occurred in the <2-mm fraction at levels of 15, 205, and 177 pCi/g for cobalt-60, cesium-137 and europium-152, respectively. Mineralogical characterization tests indicated the presence of micas in the soils. This is of importance because mica contains wedge sites that have high affinities for cesium-137. Removal of cesium-137 from these wedge sites may not be possible through scrubbing only. The mobilization of cesium-137 occupying these wedge sites can only be accomplished by disrupting and/or dissolving the mineral structures (DOE-RL 1993g).

The soil washing treatability study was performed using both physical separation and solvent extraction techniques separately, as well as tests that evaluated the effectiveness of using both techniques together. Attrition scrubbing was performed on soil size fractions in the 2-to 0.25-mm-range, while autogenous grinding was performed on the >2-mm sized fraction. Chemical extractions were used on both soil size fractions.

Attrition scrubbing tests were performed using deionized water and electrolytes. Results of the tests using deionized water indicated a >90% reduction in cobalt-60 activity, a 61% reduction in europium-152 activity, and a 26% reduction in cesium-137 activity at an optimal pulp density of 83% and an energy input of 1.43 HP-min/lb. Attrition scrubbing using an electrolyte resulted in a removal of >80% for cobalt-60, 83% for europium-152, and 39% for cesium-137. Such enhanced removal by electrolyte addition appears to be a result of the synergistic combination of scrubbing action, the improved dissolution of radionuclide-bearing surface coatings, and the reduced readsorption of solubilized contaminants onto freshly exposed surfaces of the coarse-grained soil (DOE-RL 1993g).

Autogenous grinding was performed on gravels and cobbles from the 116-C-1 trench. The process effectively removed a maximum of 85% of cobalt-60 and 97% of europium-152. However, autogenous grinding was ineffective in removing cesium-137 from the cobbles and gravels, primarily due to the high initial cesium-137 activities.

Chemical extraction was performed using soils from both trench areas. A variety of extractants were used that are typical of chemical extraction in soils, as well as some proprietary extractants. The extraction data showed that all extractants except acetic acid removed substantial fractions of cobalt-60 and europium-152 from the 2-to 0.25-mm-sized fractions of 116-D-1B trench soil. However, only the proprietary extractants were effective in removing cesium-137 from this soil fraction (85%). Extraction tests performed on gravels from the 116-C-1 trench were effective in treating cobalt-60 and europium-152, but were ineffective in treating cesium-137.

In addition to the previously discussed tests, two stage attrition scrubbing tests were performed on 2- to 0.25-mm-fractions soils using deionized water and electrolytes. The results indicated an increase in radionuclide removal over single stage scrubbing to levels of >79% for cobalt-60, 94% for europium-152, and 48% for cesium-137. Autogenous grinding experiments conducted on gravels using an electrolyte solution indicated removals of 88% for cobalt-60 and 94% for europium-152. Grinding with an electrolyte was ineffective in removing cesium-137 from gravels.

4.1.5.3.3 100 F Area Treatability Study. A bench scale treatability study was conducted using soil from the 116-F-4 pluto crib. The objective of this study was to evaluate the use of physical separation (wet sieving), treatment processes (attrition scrubbing and autogenous surface grinding), and chemical extraction methods as a means of separating radioactively-contaminated soil fractions from uncontaminated soil fractions (WHC 1994d).

Data on the distribution of radionuclide on various size fractions indicated that the soil-washing tests should e focused on the gravel and sand fractions of the 116-F-4 soil. The radionuclide data also showed that cesium-137 was the only contaminant in this soil that exceeded the test performance goal (TPG). Therefore, the effectiveness of subsequent soil-washing tests for 116-F-4 soil was evaluated on the basis of activity attenuation of cesium-137 in the gravel- and sand-size fractions.

Two types of tests (physical and chemical) were conducted to reduce the activities of cesium-137 in the particle-size fractions of 116-F-4 soil. The physical tests consisted of attrition scrubbing (2- to 0.25-mm-sized fraction) and autogenous grinding of gravel fractions. Chemical extractions were also conducted on the sand fraction.

The results of autogenous surface grinding experiments using a centrifugal barrel processor showed that 94% to 97% of total cesium-137 activity in the gravel fractions could be removed if grinding was conducted in a water medium. The data indicated that grinding was less effective when conducted in an electrolyte medium. Following autogenous surface grinding, the gravel fractions containing initial cesium-137 activities ranging from 186 to 391 pCi/g were found to contain an average residual activity of 19 pCi/g. This value is well below the TPG of 30 pCi/g for cesium-137. The autogenous surface grinding data indicated that the bulk of the contaminant activity (about 74%) was located in the firts millimeter of the gravel particle surface. The grinding data also showed that it is necessary to grind approximately a 3-mm surface layer of gravel particles to reduce the residual cesium-137 activity below the TPG. On average about 30% by weight of fines (<0.25-mm) were generated during the autogenous surface grinding experiments. The residual cesium-137 activity in the treated gravel fraction was functionally related to the quantity of fines generated.

It should also be noted that because of a limited number of experiments, factors that influence autogenous surface grinding such as consistency, uniformity of grinding, and energy requirements were not evaluated. These additional data may be needed to evaluated in detail the scale-up factors for conducting pilot- or field-scale autogenous surface grinding.

Based on the data from previous attrition-scrubbing tests on 116-D-B soil from the 100 Area, optimized attrition scrubbing tests were conducted on the sand fraction (2- to 0.25-mm) of 116-F-4 soil. Two-stage and three-stage attrition scrubbing was conducted in the presence of an electrolyte at an optium pulp density of about 79% and an energy input of 1.5 HP min/lb. The two-stage and the three-stage attrition scrubbing removed on average 50% and 60% of cesium-137 activity, respectively. The residual cesium-137 activities in scrubbed samples, ranging from 75 to 114 pCi/g, were well above the TPG for this radionuclide.

Chemical extraction experiments were also conducted on both untreated and attrition-scrubbed sand fractions from 116-F-4 soil. Previous extraction experiments indicated (DOE-RL 1993a) that a proprietary extractant (Extractant II) was the most effective of all extractants tested in removing substantial amounts of radionuclides including cesium-137 from Hanford soils. the chemical extraction data showed that one-quarter and one-half formal concentrations of Extractant II removed from 72% to 79% of the total cesium-137 activity from sand fractions resulting in residual activities that ranged from 52 to 77 pCi/g. Chemical extraction tests conducted on two-stage attrition scrubbed samples showed that the residual cesium-137 activity can be reduced to 27 pCi/g, a value below the

TPG. These data indicated that a combination of two-stage scrubbing in electrolyte followed by chemical extraction can reduce initial cesium-137 activities of 210 to 260 pCi/g in sand fraction to below the TPG with concomitant generation of 2.3% contaminated fines (on bulk soil basis).

4.1.5.4 Vitrification. Vitrification is a process that converts soil and other materials into glass or glass-like substances using heat. Vitrification immobilizes inorganics, such as metals and radionuclides, by encapsulating or incorporating them into the structure of the glass. The resulting vitrified product is a glass matrix that is highly resistant to leaching. Ex situ joule heating vitrification utilizes furnaces that have evolved from glass melters in the glass industry. The electric furnace/melter uses a ceramic-lined, steel-shelled melter to contain the molten glass and waste materials to be melted (EPA 1992).

In a typical joule-heated ceramic melter (JHCM), wastes are introduced into a molten glass bath between two electrodes which heat the contents to temperatures between 1000 and 1600°C. A cold cap is usually formed on the top of the melt as the feed is introduced and functions as the interface between the incoming material and the molten glass. The cold cap performs an important function of holding volatilized wastes, particularly metals, so that maximum contact time between the metals and the melt can occur, increasing the probability of metals dissolving in the melt (EPA 1992).

Some of the same limitations that apply to ISV also apply to JHCM. Metals in their elemental form may sink to the bottom of the melt forming an electrically conductive layer that can short the system. Other processing problems may include slow processing rates due to high melt viscosity or increased melter corrosion due to low melt viscosity. However, feed modifications and other process control adjustments can be easily made with ex situ vitrification. For example, chemicals can be added to change the melt composition to enhance the solubility of the metals as well as produce a more durable and leach resistant product.

In the FS Phases 1 and 2 (DOE-RL 1993a), ex situ vitrification was considered in combination with a soil washing alternative to stabilize the radionuclides associated with the fines prior to disposal. The rigorous action of soil washing should remove any radionuclides capable of leaching from the soil. It is unlikely that anything not removed from soil washing will be removed by contact with rainwater. Also, the disposal facilities being considered are designed to prevent infiltration, and therefore possible migration of contaminants. Thus, ex situ vitrification will not be considered further.

4.1.5.5 Compaction.

4.1.5.5.1 Description. Compaction of solid waste is a well established technology developed for the processing and disposal of municipal waste. Materials from burial grounds such as soft wastes and scrap metals are amenable to compaction. The method which achieves the highest degree of compaction is baling. A baler consists of a series of hydraulic rams that compresses solid waste into a confined space. The resulting bales can be bound with wire into dense manageable bricks. Baled waste is less prone to methane production, generally will not support combustion, and produces leachate of a less concentrated nature (Corbitt 1990).

A typical baler consists of three rams which provide compression in three dimensions (Figure 4-8). The first ram provides compaction in a horizontal direction to a pre set dimension, the second ram compresses in a horizontal direction perpendicular to that of the first also to a pre set dimension, the third ram provides vertical compression to a predetermined gauge pressure. Many commercially available balers do not require material separation prior to compaction. Materials are loaded into a conveyor system which supplies the charging box of the baler.

Depending on the type of unit, the volume of material can be reduced to 10% that of the original volume. Final densities vary based on the types of materials processed and the ram pressure. Compression pressures vary from 500 to 4,000 psi. Below 1,000 psi unstable bales will be produced regardless of other parameters. Low pressure baling generally will require banding while high pressure baling does not. Approximately 20 to 50 tons of waste can be processed per hour. Typically, the high pressure balers are only available in the higher capacities (50 tons/hour). Final block sizes are typically 1 m by 1 m by 1.4 m (39 in. by 39 in. by 55 in.) (GEC 1975).

4.1.5.5.2 Similar Study. The American Public Works Association (APWA) performed compaction experiments with a three-stroke scrap baler donated by General Motors Corporation in a test program conducted in 1970 (GEC 1975). Experiments were performed on a variety of municipal wastes consisting mostly of household refuse. Samples were subjected to pressures ranging from 500 to 3,500 psi with a few samples subjected to 6,000 psi. Seventeen seconds was required to make the final high pressure stroke. Bales produced typically measured 0.4 m by 0.5 m by 0.35 m (16 in. by 20 in. by 14 in.) high. Average densities obtained at 3,500 psi was 2,500 lb/yd^3. Bale expansion was about 30% after compression at 3,500 psi. Compaction pressures of less than 1,000 psi produced fragile bales. Bale stability increased with increasing pressure up to 2,000 psi. Pressures above 2,000 psi produced no apparent increase in bale stability. Increased bale stability also resulted from increasing the amount of time which compaction pressures were maintained. Leachate was produced by the baling process and pollutants were detected by analyses. The potential for leachate production by the compressed waste was reduced through reduction in the permeability of the waste. The coefficient of permeability of compressed refuse was reduced from 13 m/day to 0.6 m/day (42.6 ft/day to 2.0 ft/day) with an increase in wet density from 965 lb/yd^3 to 1,917 lb/yd^3. Tests were also conducted to measure gas production by taking compacted samples, immersing them in water baths at different temperatures, and buffering the solutions to high pH values to encourage gas production. The low permeability of the waste prevented penetration of the alkaline solution at a rate fast enough to counteract the internally generated organic acids. As a result gas generation ceased in tests after three days. The APWA tentatively concluded that baling may present a lesser degree of potential environmental control problems. At an experimental balefill site in Georgia no shifting had been observed after 6 years of operation. A series of tests were also performed to assess handleability of the bales. The APWA concluded that strapping offered no real advantage in high-pressure bales. Rail haul tests of 700 miles produced no damaged bales. The tests pointed out that bales should be tightly loaded into the railcars (GEC 1975).

All of this information indicates that once the waste is compacted, the bales are extremely stable structurally, enhancing this technologies ability in satisfying health and safety issues and protecting the public to a high degree.

4.1.6 Disposal

Onsite disposal is retained for evaluation as an applicable technology. The two technologies that exist for onsite disposal are trenches and vaults. It should be noted that prior to implementation of a disposal option, the waste acceptance criteria and availability of a disposal facility must be carefully evaluated.

4.1.6.1 Trench Disposal. Burial trenches consist of below grade excavations for waste disposal. Unlined disposal trenches have been used in the past at the site. Applicable technology for trench disposal has been developed incorporating RCRA compliant designs. Currently a RCRA compliant facility, the W-025 Radioactive Mixed Waste Land Disposal Facility, is under construction in the 200 Area. An additional facility is currently in the conceptual design phase, the ERDF, which is planned to accept wastes generated from environmental restoration activities including remediation of the 100 Areas. The construction of the W-025 facility is planned to be complete in 1994. The construction of Phase I of the ERDF is planned to be complete by the end of 1996. The entire ERDF will be completed at a later date. Both facilities will incorporate an appropriate surface barrier as discussed in Section 4.1.3. The design of these facilities is discussed in the following paragraphs.

4.1.6.1.1 The W-025 Radioactive Mixed Waste Land Disposal Facility. The major components of the W-025 facility are: the disposal trench; a contaminated water temporary storage facility; utility systems such as electrical and communications; a security system; a stormwater management system; and a control building. The facility is located within the existing Low Level Burial Area No. 5 between Trenches 39 and 47 in the 200 West Area. The disposal trench is a rectangular landfill with a RCRA compliant liner. The trench will provide a burial capacity of 69,000 yd^3 (53,000 m^3), however, due to the required soil cover, the anticipated waste capacity is approximately 28,000 yd^3 (21,000 m^3). The landfill will be constructed with a primary leachate collection system, a secondary leachate collection system, and a RCRA compliant cover. Transport to the facility will be by truck from the source areas. The design and operations of the facility are presented in the Design Report (WHC 1990).

The facility will accept solid waste in accordance with *Hanford Site Solid Waste Acceptance Criteria* (WHC 1993a) which essentially implements the requirements of RCRA and DOE (DOE Order 5400.5).

Wastes will be placed in the facility in horizontal lifts with each lift being completed across the entire base of the landfill prior to beginning the next lift. Each lift will consist of approximately a 1.5 m (5 ft) thickness of waste followed with 0.3 to 0.6 m (1 to 2 ft) of clean soil cover. High activity wastes may be placed by constructing concrete block walls to shield workers. During waste placement, dust will be controlled by the use of clean soil cover and liquid spray suppressants. The upper surface of the waste will be sloped at a final grade of 2% to provide drainage for the final cover.

The final cover for the disposal trench will be consist of a Hanford Barrier. It may be possible to use some of the materials excavated for the trench in the construction of the barrier.

4.1.6.1.2 Environmental Restoration Disposal Facility. The major components of the ERDF are: the waste disposal trench; a contaminated water pumping and treatment facility; a sanitary waste water system; a decontamination facility; a water supply, pumping, treatment, and distribution system; utility systems such as electrical and communications; a security system; fuel and chemical storage and dispensing areas; a stormwater management system; and an operations building. The ERDF will be located east of the existing 200 West Area, south of the proposed 16th Avenue extension. The ERDF consists of a single disposal trench with a RCRA compliant liner. The trench is conceptualized to provide a burial capacity of 6 million yd^3 (4.6 million m^3) which can be expanded to an ultimate burial capacity of up to 28.5 million yd^3 (21.8 million m^3). The trench will be constructed with a leachate collection system, a leak detection system, and a RCRA compliant cover. Both transport by rail and by truck from the source areas to the facility is being explored. Offloading facilities will be provided at the ERDF for rail transported materials. The design and operations of the trench are presented in the Conceptual Design Report (Army 1994).

Preliminary waste acceptance applicability criteria have been established for the facility based on *Hanford Site Solid Waste Acceptance Criteria* (WHC 1993a). The types of wastes which will be accepted have not been finalized; however, the draft waste acceptance applicability criteria (Army 1994) allows:

- no waste higher than Category 3, which is defined by a formula that is a function of the identity and mass fraction of each constituent of the waste (WHC 1993a)
- no TRU waste
- no waste containing free liquids
- no waste containing decomposable material in concentrations >10% of the waste volume
- waste must be compatible with the liner system considering 30 year performance applicability criteria
- single use container shall not contain more than 10% volume of voids and decomposable material
- soil in single use containers shall be compacted to approximately 95% modified proctor density (ASTM D 1557)

- void space between the surface and top of a single use container must be grouted to fill all voids.

Waste will be placed in the trench from west to east in two benches, each 11 m high. Waste will be covered with clean fill at the end of each working day. Contaminated material will be dumped, spread, and compacted to about 95% of Modified Proctor. Single use containers will be placed on the trench floor or on the top of the first waste lift. Irregularly shaped objects such as demolition debris will be flood-grouted as needed to reduce void space and reduce potential for settlement. During waste placement, dust will be controlled by the use of clean soil cover and liquid spray suppressants. The upper surface of the waste will be sloped at a final grade of 2% to provide drainage for the final cover.

The final cover for the disposal trench will consist of a Hanford Barrier (Army 1994). It may be possible to use some of the materials excavated for the trench in the construction of the barrier.

4.1.6.2 Vault Disposal. Vaults are engineered containment facilities that provide a maximum of lateral and vertical confinement. Vaults were identified in the FS Phases 1 and 2 (DOE-RL 1993a) for disposal of organic wastes and TRU waste.

Decay of organic waste disposed of in a standard landfill promotes subsidence and subsequent failure of the landfill cover. The vault would be designed to prevent subsidence after the organic wastes had decomposed. This concept has been incorporated into the disposal trench design and, as a result, the separate vault concept has been abandoned. The most recent design of the ERDF includes injection grouting of decomposable wastes, as necessary.

Transuranic waste originally identified for disposal in vaults will eventually be disposed of off site. The TRU wastes will be handled as defined in the *Hanford Site Solid Waste Acceptance Criteria Manual* (WHC 1993a). The waste will be stored in the 200 Area, analyzed, packaged in the Waste Receiving and Packaging Facility, and eventually shipped to the Waste Isolation Pilot Plant in Carlsbad, New Mexico.

Transuranic waste has not been identified in any of the 100 area investigations since the FS Phases 1 and 2. Transuranic waste is therefore not expected.

4.1.7 Innovative Technologies

The DOE's Environmental Management (EM) Office of Technology Development (OTD) (EM-50) is managing an aggressive national program for applied research, development, demonstration, testing, and evaluation. The objective of this program is to develop technologies to cleanup the DOE nuclear production and manufacturing sites and to manage DOE generated wastes more cost-effectively than current environmental cleanup technologies. The program is addressing several major problem areas including groundwater and soil cleanup; and waste retrieval and processing. This Process Document evaluates two of the OTD's previously developed technology alternatives: in situ vitrification and the modified RCRA barrier. In addition to these two mature technologies, there is a suite of mutually complimentary technologies for environmental restoration in various stages of development and demonstration that will be ready for implementation in the near future.

4.2 DESCRIPTION OF ALTERNATIVES FOR SOIL AND SOLID WASTE

Alternatives associated with the six GRA identified in the FS Phases 1 and 2 are subsequently described. The GRA are:

- No Interim Action
- Institutional Controls
- Containment
- Removal/Disposal
- In Situ Treatment
- Removal/Treatment/Disposal.

For each alternative, site characteristics or conditions which are prerequisite to effective application of the alternative (applicability criteria) are presented. Additional alternative components (enhancements) which may be incorporated into the alternatives on a case by case are also presented. The identification of enhancements increases the number of sites which may be effectively addressed by the developed alternatives, and thereby minimizes the need for site-specific development of alternatives in the subsequent operable unit-specific FFS.

Although single alternatives may be applied to the initial IRM, a combination of alternatives may be preferable as more information is gathered through the observational approach. The results of this Process Document on operable unit specific FFS will be used in combination with information gathered during initial IRM implementation to evaluate the appropriate alternative or combination of alternatives.

4.2.1 No Interim Action General Response: Alternatives SS-1 and SW-1

The no interim action alternatives for soil and solid waste sites are SS-1 and SW-1, respectively. The National Contingency Plan (55 Federal Register 8666 et seq.) requires that a "no interim action" alternative be retained to serve as a baseline for evaluating remedial alternatives. The alternative represents a situation where no restrictions, controls, or active remedial measures are applied to the site. No interim action implies a scenario of "walking away from the site," however, the decisions being made in this document are for interim records of decision and do not constitute final actions. Contamination present is allowed to dissipate through natural attenuation processes. The acceptability of this alternative is initially evaluated in the QRA. Generally speaking, a site that is justified as an IRM candidate through the LFI process will not be effectively addressed by this alternative, however exceptions do exist. The final decision on the applicability of no interim action is addressed on a site by site basis in the operable unit-specific FFS where site-specific information is reviewed against the RAO.

The no interim action alternatives require that the following criterion be met prior to implementation: the site poses no threat to human health and the environment or, the site has been effectively addressed in a prior action. No enhancements have been identified for the no action alternative.

4.2.2 Institutional Controls General Response: Alternatives SS-2 and SW-2

The institutional controls alternatives for soil and solid waste sites are Alternatives SS-2 and SW-2, respectively. The alternatives involve the following technologies:

- deed restrictions (Section 4.1.1.2)
- groundwater surveillance monitoring (Section 4.1.1.1).

Deed restrictions would be incorporated at the waste site if and when DOE relinquishes control of the waste site. Groundwater surveillance monitoring will be conducted at the waste site where institutional controls are used. The present network of groundwater monitoring wells and sampling schedule are deemed adequate for the monitoring of impacts to groundwater.

The alternative does nothing to limit exposure to human or ecological receptors or protect groundwater. Therefore, the alternative is appropriate to waste site groups where the contaminant concentrations presently meet the PRG. Based on the PRG calculation method, sites which contain radionuclides, but concentrations are below PRG, require institutional controls until the year 2018. The site may then be released with no further action.

The institutional controls alternatives require that the following applicability criterion be met prior to implementation: contaminant concentrations presently meet the PRG.

No enhancements have been identified for the institutional controls alternatives.

4.2.3 Containment General Response: Alternatives SS-3 and SW-3

The containment alternatives for soil and solid waste sites are Alternatives SS-3 and SW-3, respectively. The alternative involves applying the following technologies:

- Modified RCRA Barrier (Section 4.1.3.1.2)
- surface water controls (Section 4.1.3.2)
- groundwater surveillance monitoring (Section 4.1.1.1)
- deed restrictions (Section 4.1.1.2).

Operations for this alternative commence with the design of the appropriate barrier for the waste site area. The waste site area is defined as the at-grade surface area projected from the waste site (i.e., the projection of the pipelines and the associated contaminated soil). Because the possibility that high level radioactive wastes exist in the soil and solid waste sites is very small (Miller and Wahlen 1987 and Dorian and Richards 1978), the Modified RCRA

Barrier is selected as the appropriate barrier type. Future modifications can be made to this alternative to incorporate the Hanford Barrier, should characterization or monitoring activities of waste sites where RCRA barriers have been placed indicate more protection is needed. The lateral extent of the barrier is delineated based on the extent of contamination present at the site to be covered. Additional investigations are required to adequately locate and delineate the extent of contamination. For the purpose of this study, an additional 12.2 m (40 ft) of effective barrier is assumed to be provided laterally beyond the limits of contamination. The effective barrier is defined as the asphalt layer.

Surface water controls may be implemented both during and after construction of the barrier. Groundwater surveillance monitoring will be coordinated with the existing groundwater monitoring programs. The present network of groundwater monitoring wells and sampling schedule are deemed adequate for the monitoring of impacts to groundwater. Deed restrictions are provided for the area of the completed barrier and groundwater which may be impacted by the site.

The RAO are met by eliminating the exposure pathways through the construction of a physical barrier inhibiting contact and through protection of the groundwater by minimizing the spread of contamination by erosion, leaching, or mobilization by biotic activity.

The containment alternatives require that the following applicability criteria be met prior to implementation:

- contaminant concentrations presently exceed the PRG
- contaminant concentrations do not exceed levels which may impact groundwater under the reduced infiltration scenario.

No enhancements have been identified for the containment alternatives.

4.2.4 Removal/Disposal General Response: Alternatives SS-4 and SW-4

The removal/disposal alternatives for soil and solid waste sites are Alternatives SS-4 and SW-4, respectively. The alternatives involve the following technologies:

- removal (Section 4.1.2)
- disposal (Section 4.1.6.1).

Operations for this alternative commence with the removal of soils and solid wastes. The removal operation is described in detail for each waste site group in Section 4.1.2. The removal technology provides that low activity contaminated materials are characterized and segregated as excavation proceeds using an observational approach. Materials removed are segregated as necessary for transportation to the disposal facility. Soils may be disposed in either the W-025 or ERDF depending upon waste acceptance criteria and availability. Solid waste found in the burial grounds shall be disposed in the ERDF due to the restrictive acceptance applicability criteria for W-025. Therefore, actions at solid waste sites shall not occur until the ERDF is available (anticipated by end of 1996). Both capacity and waste acceptance criteria must be evaluated prior to determination of the applicable disposal site.

The RAO are met by removing the contaminated material which exceeds the PRG. Risk to human and ecological receptors is eliminated by the physical removal of the contaminants from the site. Excavation proceeds to the depth required to remove contaminants exceeding protectiveness of groundwater concentrations.

The removal/disposal alternatives require that the following applicability criterion be met prior to implementation: contaminant concentrations presently exceed the PRG.

No enhancements have been identified for the removal/disposal alternatives.

4.2.5 In Situ Treatment General Response: Alternatives SS-8A, SS-8B, and SW-7

The in situ treatment alternatives vary considerably from soil to solid waste sites. The following sections will discuss each alternative separately.

4.2.5.1 Alternatives SS-8A and SS-8B. Two in situ treatment alternatives are provided for the soil waste sites. The original alternative (SS-8A) is applicable to all soil waste sites with the exception of the effluent pipelines. This alternative involves the following technologies:

- ISV (Section 4.1.4.3)
- surface water control (Section 4.1.3.2)
- deed restrictions (Section 4.1.1.2)
- groundwater surveillance monitoring (Section 4.1.1.1).

The ISV technology is effective in immobilizing contaminants which reach of depth of no more than 5.8 m (19 ft). provide extent of contamination has been verified. After the waste site has been vitrified, the area is backfilled with the clean soils to a minimum of 1 m (3 ft) above the vitrified block of soil. Deed restrictions are provided for the area and groundwater which may be impacted by the site is monitored. The present network of groundwater monitoring wells and sampling schedule are deemed adequate for the monitoring of impacts to groundwater.

The RAO are met by eliminating the exposure pathways through the solidification of the contaminated area and through the addition of backfill. The protection of the groundwater is met by minimizing the spread of contamination by erosion, leaching, or mobilization by biotic activity.

The Alternative SS-8A requires that the following applicability criteria be met prior to implementation:

- contaminant concentrations presently exceed the PRG
- contaminant zone does not exceed a thickness of 5.8 m (19 ft).

An additional alternative has been developed for the pipeline sites (SS-8B). This alternative involves the following technologies:

- void grouting (Section 4.1.4.1.1)
- Modified RCRA Barrier (Section 4.1.3.1.2)
- surface water controls (Section 4.1.3.2)
- groundwater surveillance monitoring (Section 4.1.1.1)
- deed restrictions (Section 4.1.1.2).

Pipelines shall be surveyed by video prior to grouting. These surveys will assist in the determination of whether grouting is feasible as a remedial measure. If the camera survey of the pipeline shows no breaches in pipe integrity, grouting would be a feasible remedial measure. If grouting is feasible the survey will help determine proper injection grout mixture(s) and appropriate locations of injection points. Large volumes of grout will be needed to backfill the lines; for example approximately 1 yd^3 (0.76 m^3) of grout is required per foot of 1.7-m (66-in.) diameter steel pipe, approximately 3,200 m of 1.7 m (10,500 ft of 66 in.) line exists in the 100 BC Area alone. Success of the grouting process will be determined by the volume of grouting material pumped into the pipe compared to the annular volume of pipe to be grouted. The closer this ratio is to unity, the more successful the grouting. Should breaches in pipe integrity be observed during camera surveys, grouting is not the appropriate remedial measure.

Areas surrounding the effluent pipelines which have exterior soil contamination will include the addition of a modified RCRA barrier. After grouting activities have been completed, operations will commence with the design of the barrier. The lateral extent of the barrier is delineated based on the extent of contamination present at the site to be covered. Additional investigations are required to adequately locate and delineate the extent of contamination. For the purposes of this study, an additional 12.2 m (40 ft) of effective barrier is assumed to be provided laterally beyond the limits of contamination. The effective barrier is defined as the asphalt layer. Surface water controls must be implemented both during and after construction of the barrier. Groundwater surveillance monitoring will be coordinated with the existing groundwater monitoring programs. The present network of groundwater monitoring wells and sampling schedule are deemed adequate for the monitoring of impacts to the groundwater. Deed restrictions are provided for the area of the completed barrier and groundwater which may be impacted by the site is monitored.

The RAO are met by reducing the potential for settlement and immobilizing waste through encapsulation. Additionally, the RAO are met by eliminating the exposure pathways through the construction of a physical barrier by inhibiting receptor contact and through protection of the groundwater by minimizing the spread of contamination by erosion, leaching, or mobilization by biotic activity.

The Alternative SS-8B requires that the following applicability criteria be met prior to implementation:

- contaminant concentrations presently exceed the PRG

- contaminant concentrations do not exceed levels which may impact groundwater under the reduced infiltration scenario.

4.2.5.2 Alternative SW-7. The Alternative SW-7 is applicable to all solid waste sites and is similar to alternative SW-3 with the addition of in situ treatment. The alternative involves the following technologies:

- dynamic compaction (Section 4.1.4.2)
- Modified RCRA Barrier (Section 4.1.3.1.2)
- surface water controls (Section 4.1.3.2)
- groundwater surveillance monitoring (Section 4.1.1.1)
- deed restrictions (Section 4.1.1.2).

As originally proposed in the FS Phases 1 and 2 (DOE-RL 1993a) this alternative also included vibration-aided grout injection. This technology has been eliminated for the following reasons:

- The application of the vibrated-aided grout injection technology directly conflicts with the application of dynamic compaction. After dynamic compaction, the densified ground will be much less amenable to grouting since the pore space is reduced. The mechanics of the compacted ground may not allow vibration to enhance mixing of the grout with densified materials. Applied prior to grouting could result in incomplete mixing of the ground with grout but enough stabilization to render dynamic compaction ineffective.

- The success of the grouting program may be very difficult to verify. Verification depends on intrusive testing, which may be inconclusive in heterogeneous environments such as the burial grounds.

- Dynamic compaction in itself is a demonstrated technology for compaction and stabilization of buried wastes. The Modified RCRA Barrier provides near total elimination of the driving forces for the production of leachate. Grouting would provide little added protection at a great expense.

The alternative is implemented by stabilizing the waste site by using dynamic compaction. A test should be performed to optimize the design of the weight, drop pattern, and dropping parameters. For the purposes of this study the parameters are assumed to be the same as that used at the DOE Savannah River site (Section 4.1.4.2). After dynamic compaction, the activities of alternative SW-3 are followed.

The RAO are met by eliminating the exposure pathways through the construction of a physical barrier by inhibiting receptor contact and through protection of the groundwater by minimizing the spread of contamination by erosion, leaching, or mobilization by biotic activity. The inclusion of dynamic compaction increases the long-term effectiveness by lowering the leachability of the waste and by reducing the potential for settlement and subsequent failure of the barrier.

Alternative SW-7 requires that the following applicability criteria be met prior to implementation:

- contaminant concentrations presently exceed the PRG

- contaminant concentrations do not exceed levels which may impact groundwater under the reduced infiltration scenario.

No enhancements have been identified for the in situ treatment alternatives.

4.2.6 Removal/Treatment/Disposal General Response: Alternatives SS-10 and SW-9

The removal/treatment/disposal alternatives vary considerably from soil to solid waste sites. The following sections will discuss each alternative separately.

4.2.6.1 Alternative SS-10. Alternative SS-10 is applicable to the soil waste sites. The alternative involves the following technologies:

- removal (Section 4.1.2)
- thermal desorption (Section 4.1.5.1)
- soil washing (Section 4.1.5.3)
- disposal (Section 4.1.6.1).

As originally proposed in the FS Phases 1 and 2 (DOE-RL 1993a) this alternative also included ex situ vitrification. This technology has been eliminated for the following reasons:

- Stabilization of thermal desorber residues prior to disposal will do little to reduce risk at the disposal site. If needed, these residues can be grouted in place at the ERDF.

- With soil washing, contaminants will be in contact with large volumes of water during wet sieving and extractants during attrition scrubbing. It is unlikely that any remaining residuals would leach due to contact with infinitesimal volumes of water from precipitation (by comparison with the large volumes in the treatment process) (DOE-RL 1993g).

Figure 4-9 presents a flow diagram of the major operations occurring in this alternative. Generally, soils are excavated then separated into organically contaminated soils and nonorganically contaminated soils. Organically contaminated soils will be treated by thermal desorption, then recombined with remaining contaminated soil for contaminant removal by soil washing. Clean soil will be backfilled at the site, while contaminated soil will be transported to the disposal facility. All mixed waste will be transported to the ERDF for treatment, because the current draft Washington Administrative Code (WAC) for the ERDF does not restrict against treating mixed waste.

Soil washing by physical separation consists of a series of treatment operations. Initially, soils will be separated by particle size fraction using a grizzly, a vibrating screen assembly, a classifier tank and a spiral classifier. This process will result in soil fractions in the $>$2-mm range, the 2- to 0.25-mm range, and the $<$0.25-mm range. The cleaned oversized fractions will be removed and stockpiled for use as backfill. The contaminated cobble fraction will be transported to the disposal facility. The sands resulting from the initial screening process will be removed and fed into a four-cell attrition scrubber where they will be washed with an electrolyte solution. The fines generated from the attrition scrubbing will be screened and removed and the sand fraction will be fed into a second attrition scrubber where it will once again be scrubbed with an electrolyte solution. The clean sands resulting from the washing steps will be dewatered and stockpiled with the clean oversized fraction for use as backfill. The contaminated fines generated from the various soil washing steps, estimated to be approximately 5 to 15% of the total soil mass, will be transported to the disposal facility. Wastewater generated during washing will be transported to a clarifier to promote gravity settling of the solids. A combination of flocculent and polymers will be added to enhance separation. The combination of flocculent and polymers was chosen to be consistent with the field scale treatability study currently planned for the 100 Areas and shall be evaluated further in the detailed design phase. Contaminated settled and suspended fines will be dewatered and removed for disposal. Wastewater is not expected to contain radionuclides and will therefore be recycled for re-use in the washing process. Contaminated residues from thermal desorption offgas treatment and fines from soil washing will be transported to the disposal facility.

Soil washing by physical separation and attrition scrubbing is dependent upon the majority of radionuclide activity being associated with the fines ($<$0.25-mm fraction), and the fines being a minor fraction of the entire soil volume. In addition, contaminated sands that are scrubbed must contain a cesium-137 activity no higher than approximately twice the PRG based on the percent removal presented in the bench scale tests (DOE-RL 1993g). Further, it is assumed that cobbles and gravels do not contain cesium-137 activities above the PRG. Prior to implementation, a treatability study on soil washing and thermal desorption shall be performed to verify assumptions and assist in remedial design.

The RAO are met by removing the contaminated material which exceeds the PRG. Risk to human and ecological receptors is eliminated by the physical removal of the contaminants from the site. Excavation proceeds to the depth required to remove contaminants exceeding PRG. Additional benefits are gathered from the mass reduction of contaminants due to the treatment options.

The removal/treatment/disposal alternative for soil waste sites requires that the following applicability criterion be met prior to implementation: contaminant concentrations presently exceed the PRG.

Alternative enhancements which must be considered on a site by site basis include the following:

- thermal desorption will only be utilized if the waste site contains organic contaminants as defined in Section 4.1.5.1

- attrition scrubbing will be utilized based on an estimated percentage of cesium-137 concentrations in the contaminated soil volume exceeding twice the PRG.

4.2.6.2 Alternative SW-9. Alternative SW-9 is applicable to the solid waste sites. The alternative involves the following technologies:

- removal (Section 4.1.2)
- thermal desorption (Section 4.1.5.1)
- compaction (Section 4.1.5.5)
- disposal at the ERDF (Section 4.1.6.1.2).

As originally proposed this alternative also included cement stabilization of "noncompactable" wastes and treatment residues. This technology has been eliminated for the following reasons:

- The only noncompactable wastes which may be found consist of large pieces of equipment which were disposed of intact. Cement stabilization of these items is not feasible.

- Stabilization of thermal desorber residues prior to disposal will do little to reduce risk at the disposal site. If needed, these residues can be grouted in place at the ERDF.

Generally speaking, contaminated materials are removed. During removal, field detection instruments are used to ensure that the contaminated materials are properly characterized and segregated. This approach may require the designation of waste based on existing data and use of the field screening to ensure that the waste has not changed from that designation. Materials are segregated into:

- clean soil
- containerized waste
- waste contaminated with organic constituents
- compatible waste
- solids (waste that is neither compatible nor organically contaminated)
- mixed waste.

Containerized waste is set aside, inspected, and segregated into the other categories if possible. If the containerized waste does not require compaction or thermal treatment, it is sent directly to the disposal facility (i.e., handled with the solids).

Waste contaminated with organic constituents is treated by thermal desorption. While organic contamination is not expected in the 100 Area burial grounds, there is a potential for such contamination to exist. To account for this contingency, it is assumed that 5% of all waste from the burial grounds is contaminated with organic constituents.

All mixed waste will be transported to the ERDF for treatment.

The resulting treated products (compacted waste, thermally desorbed waste, and offgas treated waste) and untreated waste (solids) are then disposed of at the disposal facility. Both capacity and waste acceptance criteria must be evaluated prior to determination of the applicable disposal site.

The RAO are met by removing the contaminated material which exceeds the PRG. Risk to human and ecological receptors is eliminated by the physical removal of the contaminants from the site. Excavation proceeds to the depth required to remove contaminants exceeding protectiveness of groundwater concentrations. Additional benefits are gathered from the mass reduction and immobilization of contaminants due to the treatment options.

The removal/treatment/disposal alternative for solid waste sites requires that the following applicability criterion be met prior to implementation: contaminant concentrations presently exceed the PRG.

Alternative enhancements which must be considered on a site by site basis include: thermal desorption will only be utilized if the waste site contains organic contaminants as defined in Section 4.1.5.1.

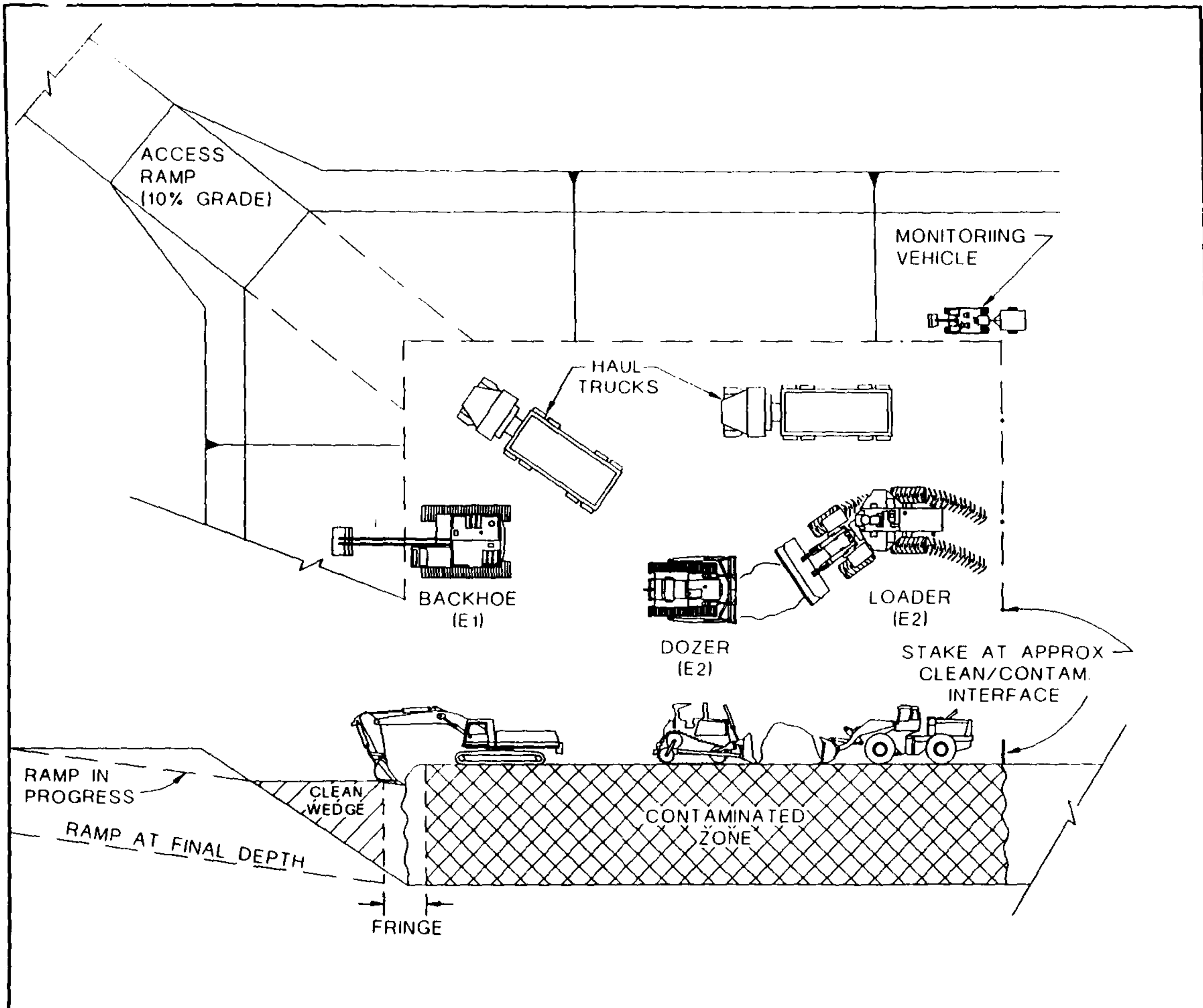

Figure 4-1 Large Site Excavation

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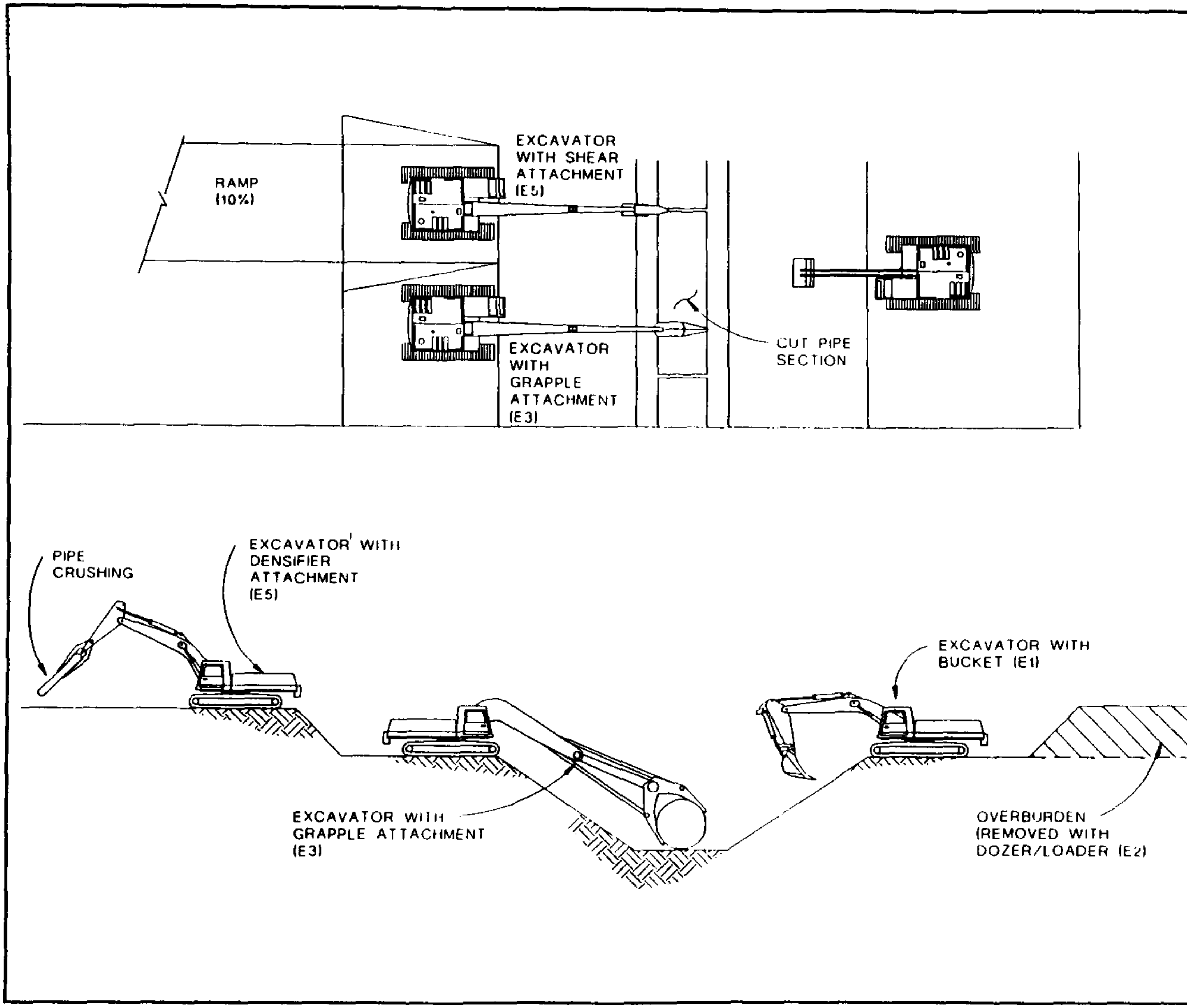

Figure 4-2 Pipeline Removal

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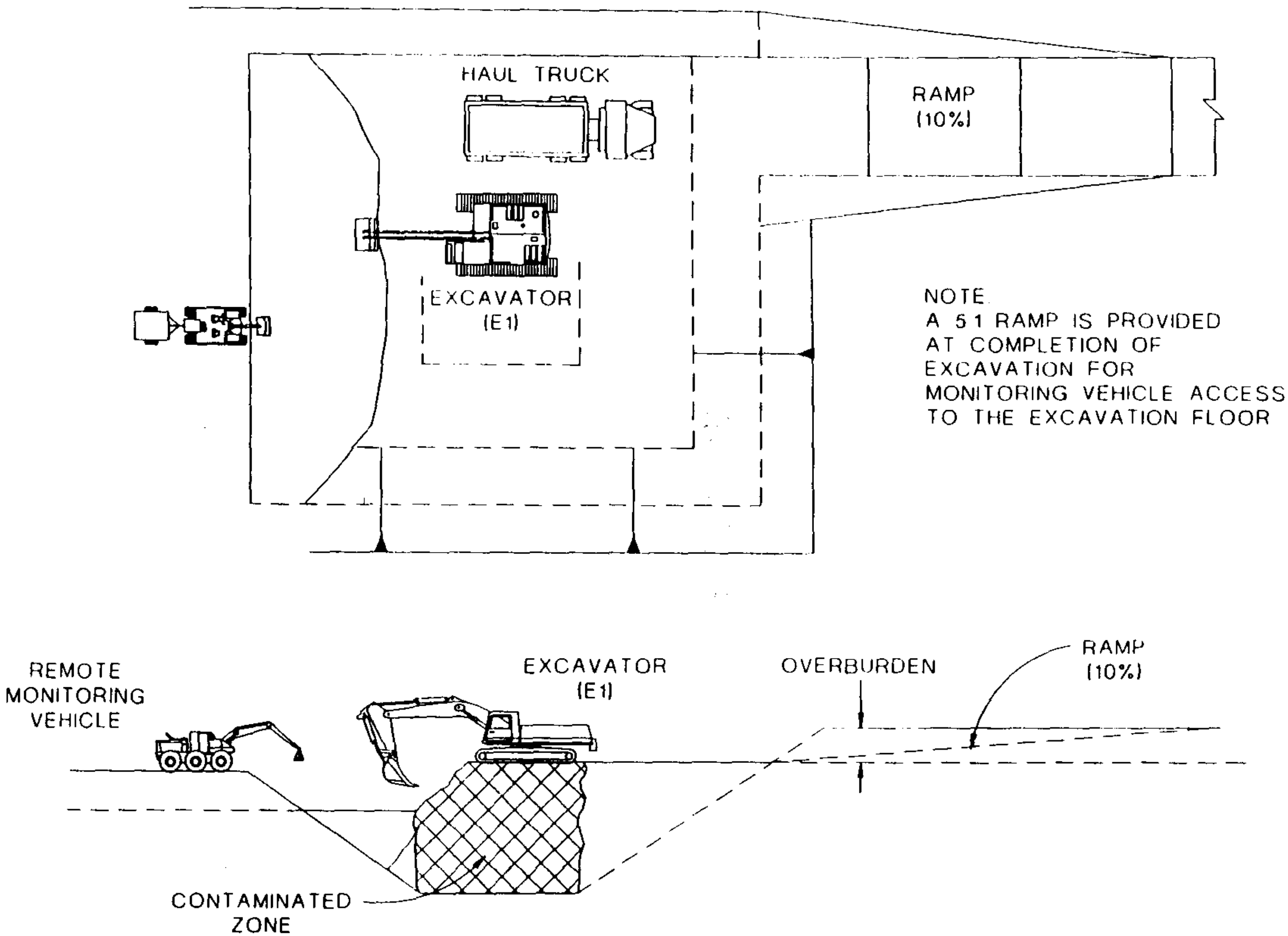

Figure 4-3 Small Site Excavation

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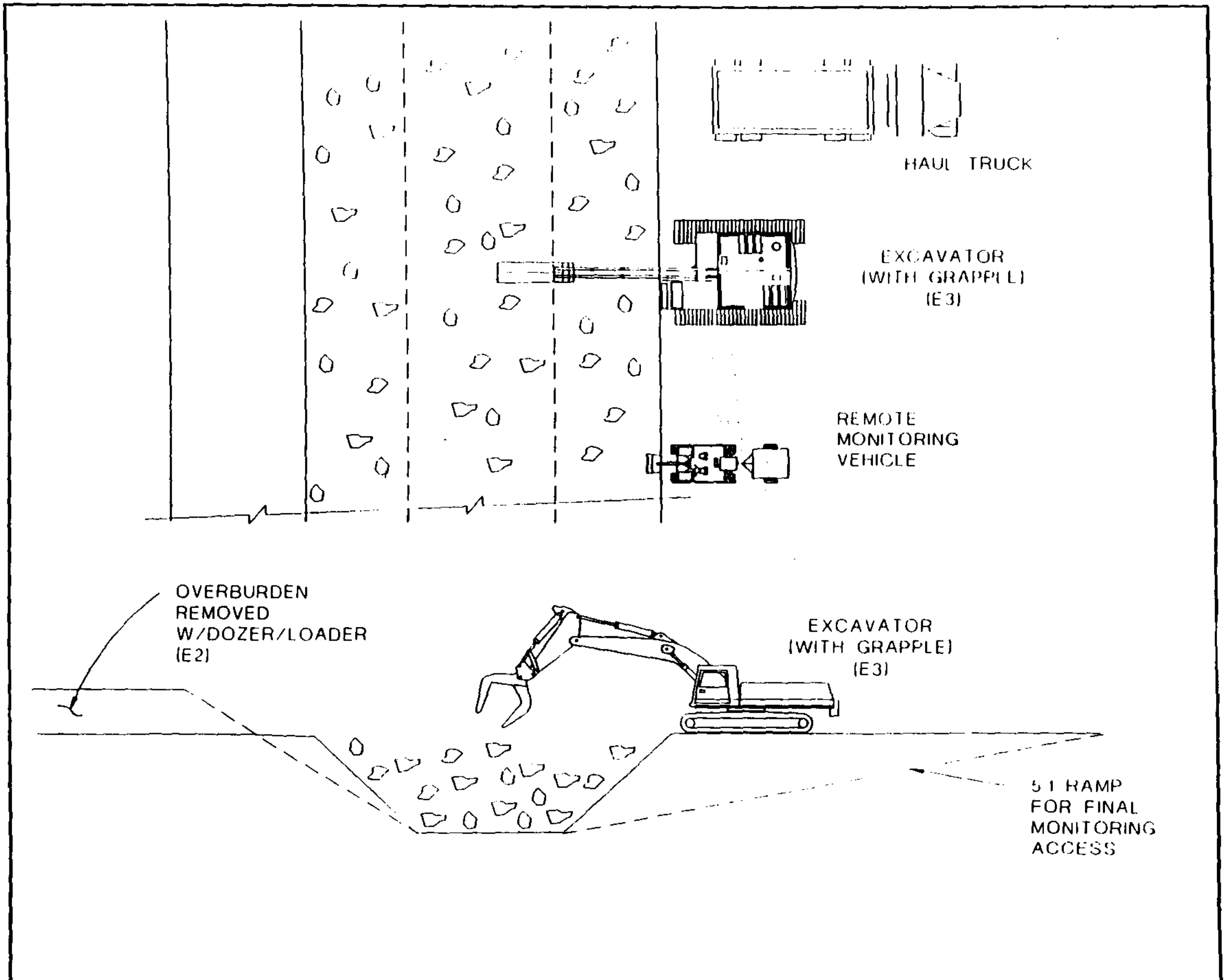

Figure 4-4 Buried Waste Excavation

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Figure 4-5 Hanford Barrier Section

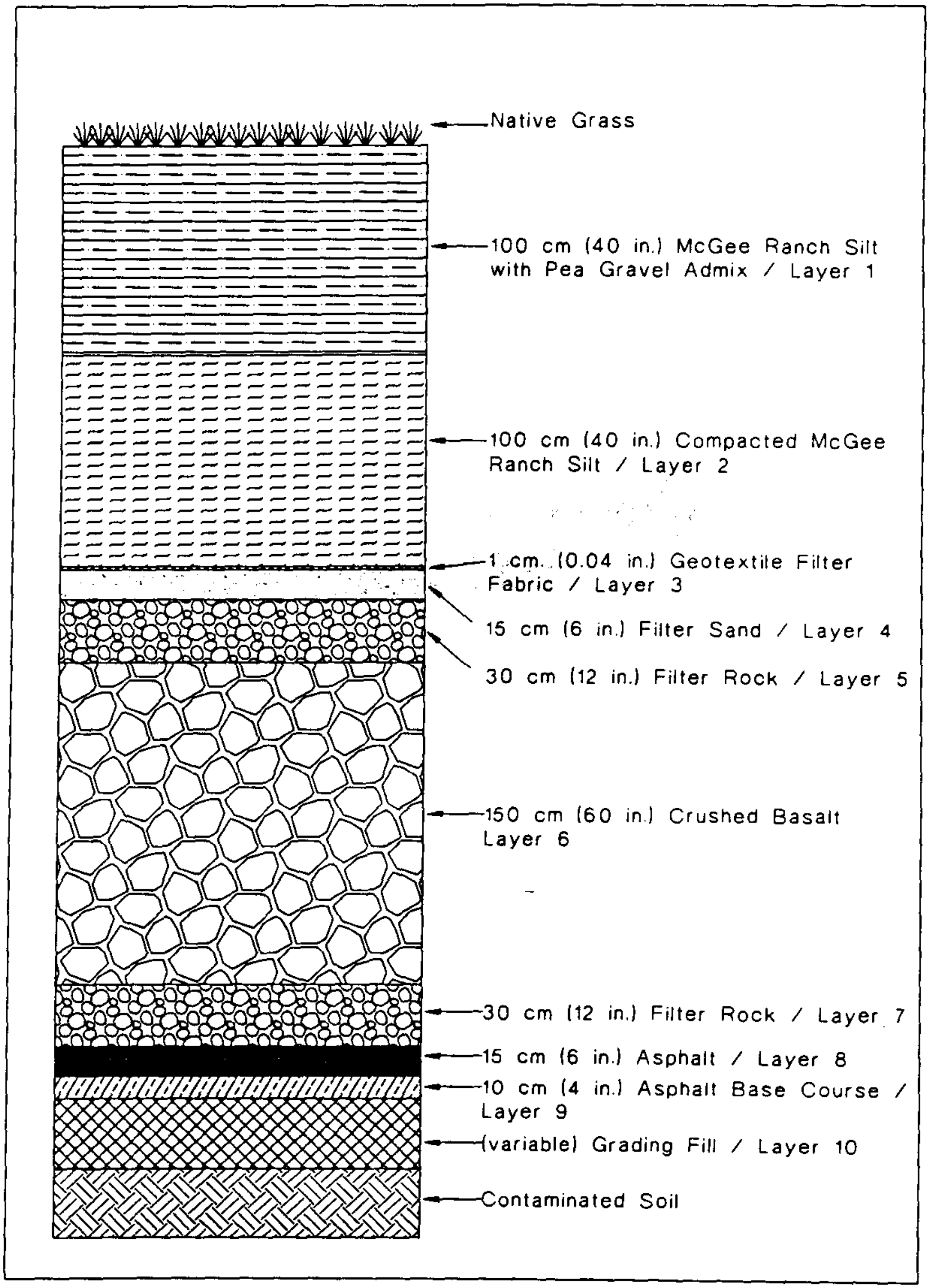

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Figure 4-6 Modified RCRA Barrier Section

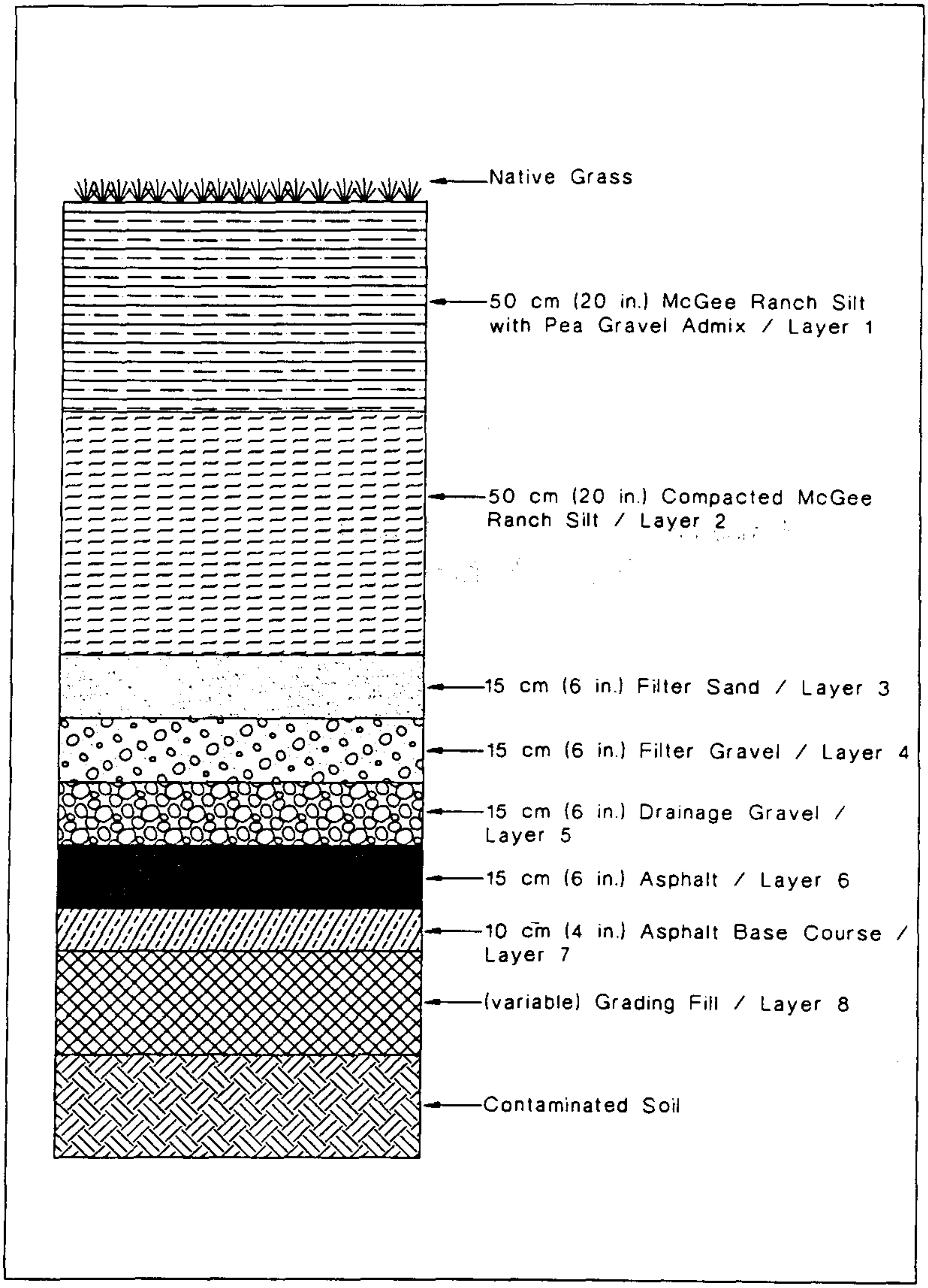

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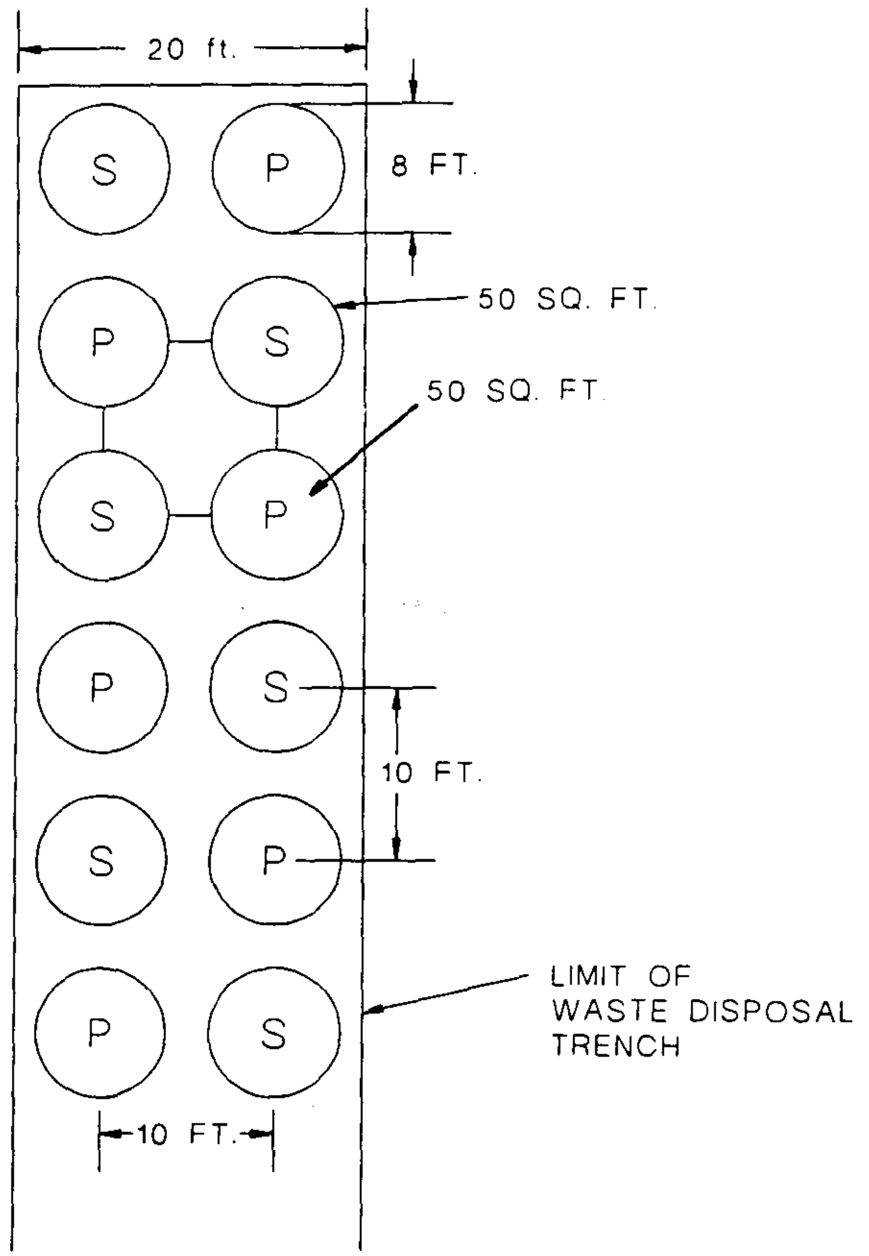
Figure 4-7 Dynamic Compaction Pattern



Grid pattern per specifications:
P = Primary drop points
S = Secondary drop points

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Figure 4-8 Compaction Press (Baler)

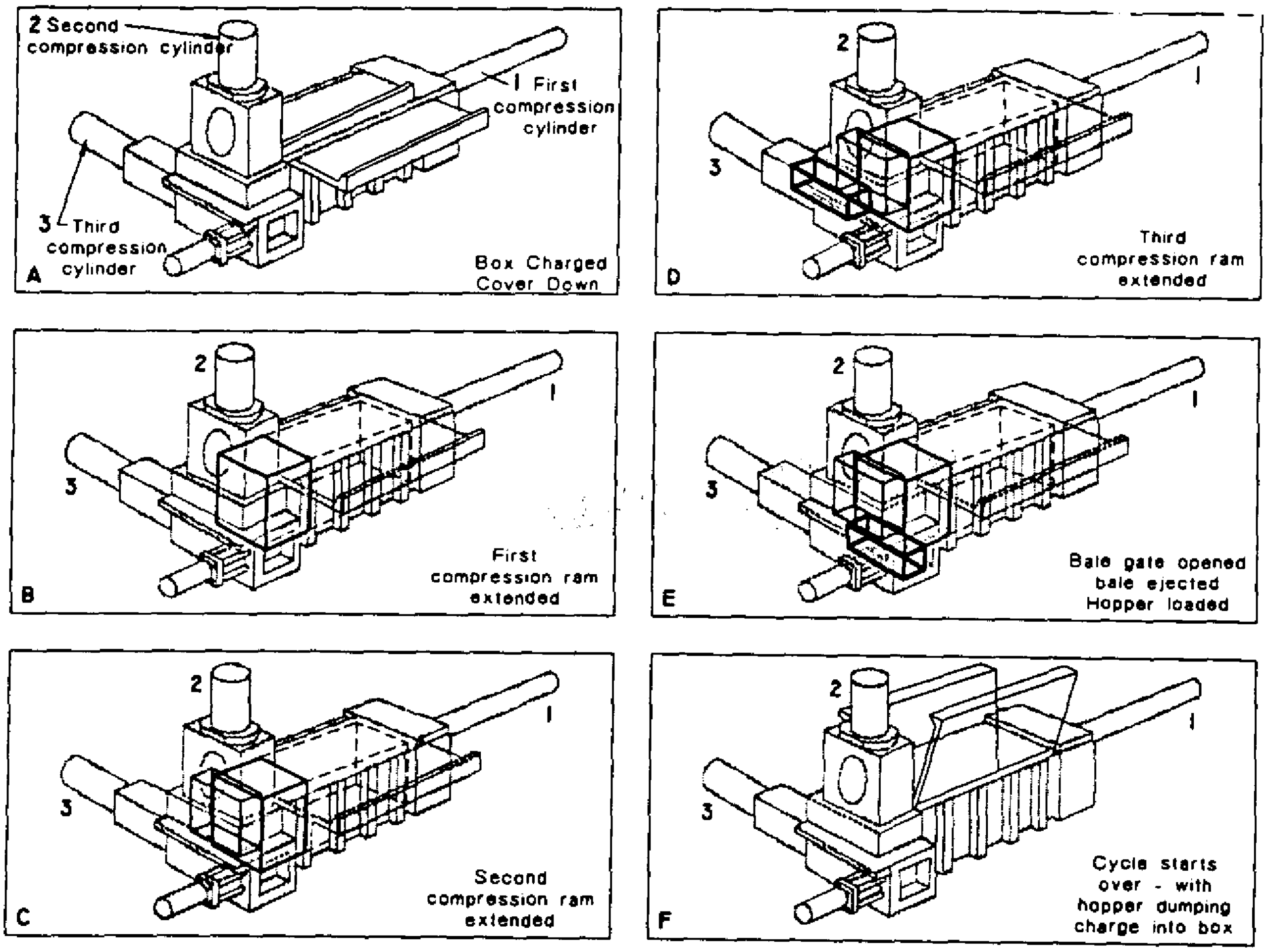

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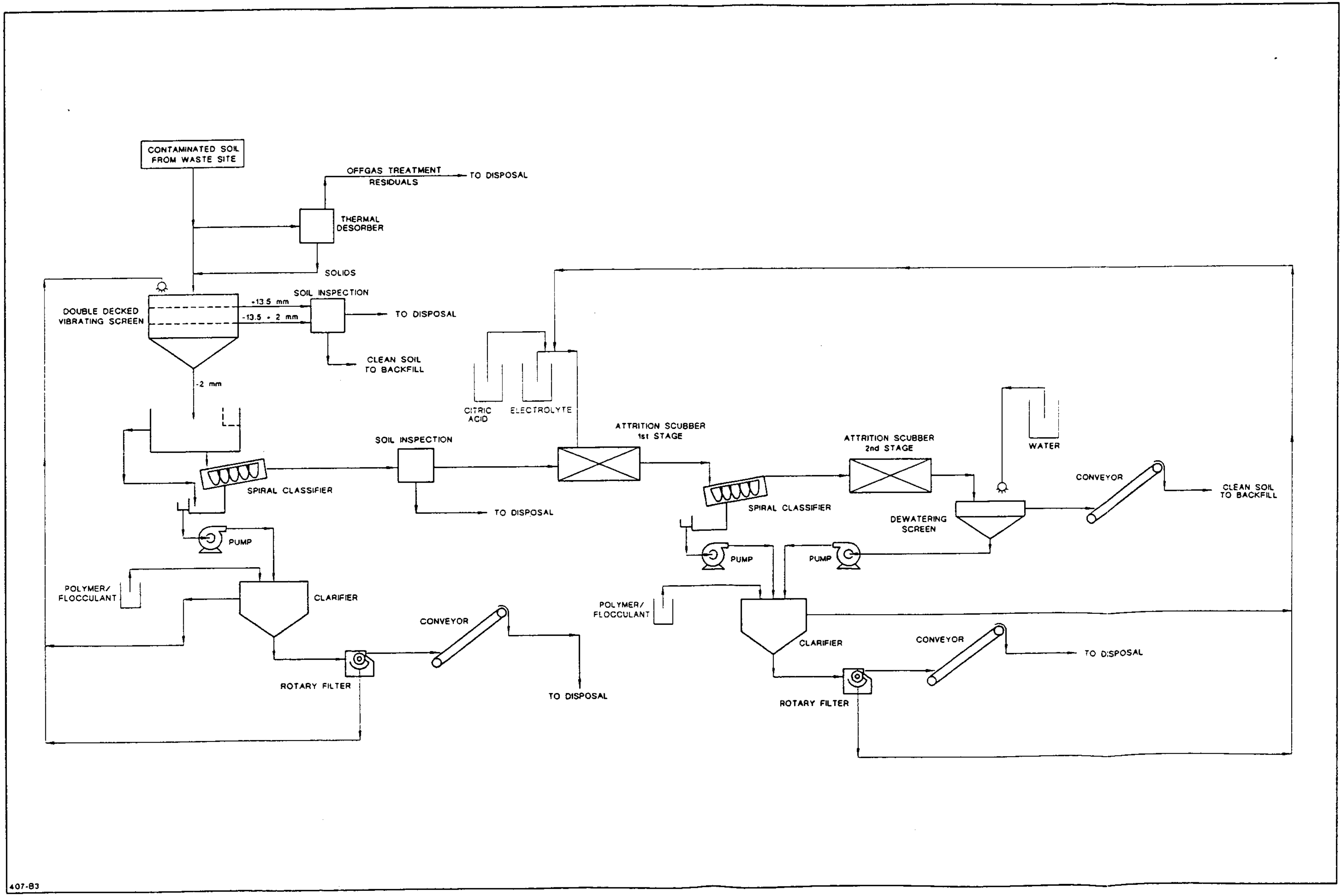
Figure 4-9 SS-10: Removal/Treatment/Disposal Flow Diagram



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5.0 DETAILED ANALYSIS

This section presents a detailed analysis of the alternatives described in Section 4.0. The purpose of the detailed analysis is to evaluate the performance of each alternative in terms of the threshold and balancing criteria presented in Table 5-1.

The detailed analysis presented in Section 5.2 focuses on the evaluation of alternatives, therefore all waste site groups for which a subject alternative may be applicable are identified and "plugged in" to the analysis of that alternative. A comparison of the waste site groups to the applicability criteria for each alternative is given in Table 5-2. Site-specific analysis will be presented in subsequent operable unit-specific FFS.

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5.1 EVALUATION CRITERIA DESCRIPTION

Nine evaluation applicability criteria have been developed by the EPA to address the statutory requirements and the additional technical and policy considerations proven to be important for selection of remedial alternatives. These evaluation applicability criteria serve as the basis for conducting the detailed analysis during the FFS and for subsequently selecting an appropriate remedial action.

The first two applicability criteria, overall protection of human health and the environment and compliance with ARAR, are termed threshold applicability criteria. Alternatives that do not protect human health and the environment or do not comply with ARAR (or justify a waiver) do not meet statutory requirements for selection of a remedy; and therefore, are eliminated from further consideration. The next five applicability criteria are balancing applicability criteria upon which the remedy selection is based. Comprehensive Environmental Response, Compensation and Liability Act guidance for conducting FS lists appropriate questions to be addressed when evaluating an alternative against the balancing applicability criteria (EPA 1988). These questions are addressed during the detailed analysis process to provide a consistent basis for evaluation of each alternative. The final two applicability criteria, regulatory (federal or state agency) and community acceptance, are evaluated following comment on this Process Document.

The nine evaluation applicability criteria are described as follows:

1. <u>Overall Protection of Human Health and the Environment</u>: This evaluation criterion assesses whether each alternative provides adequate protection of human health and the environment. Protection encompasses such concepts as reduction of risk to acceptable levels (either by reduction of concentrations or the elimination of potential routes for exposure) and minimization of threats (introduced by actions during remediation). As indicated in EPA guidance, there is substantial overlap between the protection evaluation criterion and the applicability criteria of compliance with ARAR, long-term effectiveness and permanence, and short-term effectiveness (EPA 1988). This criterion is a threshold requirement and the primary objective of the remedial program. The

remedial action durations were determined by utilizing a computer cost model developed by WHC (WHC 1994e). The durations are based on, i.e., depth, area, analytical requirements, excavation production rates, worker schedule, etc.

2. Compliance with ARAR: Each alternative is assessed for attainment of federal and state ARAR. When an ARAR is not met, the basis for justifying a waiver must be presented. Each of the following are addressed for each alternative during the detailed analysis of ARAR:

   - compliance with chemical-specific ARAR, such as maximum contaminant levels

   - compliance with location-specific ARAR, such as wetland regulations

   - compliance with action-specific ARAR, such as Closure and Post-Closure Cap Requirements.

3. Long-Term Effectiveness and Permanence: This criterion addresses the results of a remedial action in terms of risk remaining at the site after RAO are met. The primary focus of this evaluation is the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes. The following components of the criterion are addressed for each alternative:

   - Magnitude of Residual Risk: This factor assesses the residual risk remaining from untreated waste or treatment residuals at the conclusion of the remedial activities. The characteristics of the residual wastes are considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bio-accumulate.

   - Adequacy and Reliability of Controls: This factor assesses the adequacy and suitability of controls that are used to mange treatment residuals or untreated waste that remain at the site. It also assesses the long-term reliability of management controls for providing continued protection from residuals and includes an assessment of potential needs for replacement of technical components of the alternative.

4. Reduction of Toxicity, Mobility, or Volume: This criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies which permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances as their principal element. Permanent and significant reduction can be achieved through destruction of toxic contaminants, reduction of total mass, irreversible reduction in contaminant

mobility, or reduction of total volume of contaminated media. This evaluation focuses on the following specific factors for each of the alternatives:

- the treatment processes the remedy employs and the materials they treat
- the amount of hazardous materials destroyed or treated, including how the principal threat(s) are addressed
- the degree of expected reduction in toxicity, mobility, or volume measured as a percentage of reduction
- the degree to which the treatment is irreversible
- the type and quantity of treatment residuals that remain following treatment
- whether the alternative satisfies the statutory preference for treatment as a principal element.

5. Short-Term Effectiveness: Under this criterion, alternatives are evaluated with respect to their effects on human health and the environment during the construction and implementation phases of the remedial action. The following factors will be addressed for each alternative:

   - Protection of the community during remedial actions. Specifically, to address any risk that results from implementation, such as fugitive dust, transportation of hazardous materials, or air quality impacts from offgas emission.
   - Health and safety of remediation workers and reliability of protective measures taken.
   - Environmental impacts that may result from the construction and implementation of the remedial action.
   - The amount of time until the RAO are achieved.

Human health short-term impact are closely related to exposure duration, specifically, the amount of time a person may be exposed to hazards associated with the waste itself or the removal of the waste. The greater the exposure duration, the greater the potential risk. Ecological impacts are based primarily on the physical disturbance of habitat. Risks may also be associated with the potential disturbance of sensitive species such as the bald eagles which roost adjacent to the reactor areas.

The evaluation of short term risks can range from qualitative to quantitative (DOE-RL 1994a). A qualitative assessment of short term risk is appropriate considering that the risk associated with contamination at the waste sites was evaluated in a QRA. Furthermore, the sites evaluated in this FFS are high-priority waste sites that have been identified as warranting action on the near-term. The qualitative evaluation allows a sufficient differentiation between alternatives relative to short-term risks, therefore not requiring quantification. A qualitative estimation of short term risk is given below for both human and ecological receptors.

Remedial Alternative	Qualitative Short-Term Risk	
	Human	Ecological
Institutional Controls	low	low
Containment	low-medium	medium
In Situ Treatment	low-medium	medium
Removal/Treatment/Disposal	high	medium
Removal/Disposal	medium	medium

6. Implementability: The implementability criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of the required services and materials. The following factors are considered during the implementability analysis:

   - Technical Feasibility:

     - technical difficulties in constructing and operating the alternative
     - likelihood of technical problems associated with implementation of the technology leading to schedule delays
     - ease of implementing and interfacing additional remedial actions, if necessary
     - ability to monitor the effectiveness of the remedy.

   - Administrative Feasibility: Activities needed to coordinate with other offices and agencies.

   - Availability of Services and Materials:

     - availability of adequate offsite treatment, storage capacity, and disposal services, if necessary
     - availability of necessary equipment and specialists and provisions to ensure any necessary additional resources
     - availability of services and materials
     - availability of prospective technologies.

7. Cost: The detailed cost analysis of alternatives involves estimating the expenditures required to complete each measure in terms of both capital and operation and maintenance costs. Once these values have been identified and a present worth calculated for each alternative (5% discount rate), a comparative evaluation can be made.

The cost estimates presented in this section are based on conceptual designs prepared for the alternative and do not include detailed engineering data. An estimate of this type, according to EPA guidance, is usually expected to be accurate with +50 and -30%.

The cost estimates are presented in 1994 dollars and prepared from information available at the time of this study. The actual cost of the project will depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables. However, most of these factors are not expected to affect the relative cost differences between alternatives.

8. Regulatory Acceptance: This assessment evaluates the technical and administrative issues and concerns the state may have regarding each of the alternatives.

9. Community Acceptance: This assessment evaluates the issues and concerns the public may have regarding each of the alternatives.

Once the alternatives have been described and individually assessed against the applicability criteria, a comparative analysis is conducted on a group specific basis to evaluate the relative performance of each alternative in relation to each specific evaluation criterion. This is in contrast to the preceding analysis in which each alternative was analyzed independently without consideration of other alternatives.

5.2 DETAILED ANALYSIS OF ALTERNATIVES

The group profiles, defined in Section 3.0, are compared against the applicability criteria and enhancements for each alternative, defined in Section 4.0. Table 5-1 presents the result of this comparison summarizing the applicable alternatives and enhancements for each waste site group. The alternatives are then evaluated in terms of the threshold and balancing criteria (Tables 5-3 through 5-6).

A cost estimate is prepared for each waste site group based on a representative waste site. Appendix B includes a summary report of the applicable cost model for a given waste site group, a table indicating the present worth calculations, and a graph presenting the effect of disposal cost on the alternative cost. The cost models created for the 100 Area FFS are presented in *100 Area Source Operable Unit Focused Feasibility Study Cost Models* (WHC 1994e).

5.2.1 No Interim Action

The applicability criteria defined in Section 4.2.1 must be met prior to implementing the no interim action alternative. The only waste site group which meets the applicability criteria is the D&D facilities.

Based on discussion presented in Section 3.1.7, it is assumed that there is no current threat warranting an interim action. Therefore, the threshold applicability criteria are met because current contamination levels are assumed to be acceptable. Because there is no interim action, consideration of the balancing applicability criteria is not necessary.

5.2.2 Institutional Controls

The applicability criteria defined in Section 4.2.2 must be met prior to implementing the institutional controls alternative. The only waste site group which meets the applicability criteria is the seal pit cribs.

The contaminant concentrations at this waste site group do not exceed current PRG although they do require radioactive constituents to decay to 2018. The threshold applicability criteria are met because current contamination levels already meet PRG which are developed based on the threshold applicability criteria. Current Hanford Site security controls are sufficient to meet the requirements of this alternative, therefore additional costs are not incurred. Because essentially no interim action is required other than maintaining institutional controls to allow for the radioactive decay, consideration of the balancing applicability criteria is not necessary. Short term risks are low for both human and ecological receptors.

5.2.3 Containment

The applicability criteria defined in Section 4.2.3 must be met prior to implementing the containment alternative. The waste site groups which meet the applicability criteria are as follows:

- dummy decontamination cribs/french drains
- pipelines
- burial grounds.

The alternative detailed analyses for soil and solid waste site groups are discussed in Table 5-3. The applicability criteria are evaluated for all waste site groups as a whole, with specific details being noted separately for an individual group as necessary.

5.2.4 Removal/Disposal

The applicability criteria defined in Section 4.2.4 must be met prior to implementing the removal/disposal alternative. The waste site groups which meet the applicability criteria are as follows:

- retention basins
- sludge trenches
- fuel storage basin trenches
- process effluent trenches
- pluto cribs
- dummy decontamination cribs/french drains
- pipelines
- burial grounds.

The alternative detailed analyses for soil and solid waste site groups are discussed in Table 5-4. The applicability criteria are evaluated for all waste site groups as a whole, with specific details being noted separately for an individual group as necessary.

5.2.5 In Situ Treatment

The applicability criteria defined in Section 4.2.5 must be met prior to implementing the in situ treatment alternative. The waste site groups which meet the applicability criteria are as follows:

- sludge trenches
- process effluent trenches
- pluto cribs
- dummy decontamination cribs/french drains
- pipelines
- burial grounds.

The alternative detailed analyses for soil and solid waste site groups are discussed in Table 5-5. The applicability criteria are evaluated for all waste site groups as a whole, with specific details being noted separately for an individual group as necessary.

5.2.6 Removal/Treatment/Disposal

The applicability criteria defined in Section 4.2.6 must be met prior to implementing the removal, treatment, disposal alternative. The waste site groups which meet the applicability criteria are as follows:

- retention basins
- sludge trenches
- fuel basin trenches

- process effluent trenches
- pluto cribs
- dummy decontamination cribs/french drains
- pipelines
- burial grounds.

The alternative detailed analyses for soil and solid waste site groups are discussed in Table 5-6. The applicability criteria are evaluated for all waste site groups as a whole, with specific details being noted separately for an individual group as necessary. It should be noted that the reduced volume achieved through treatment will lessen the burden on the capacity of the disposal facility.

Table 5-1 Soil and Solid Waste Site Group Remedial Alternatives and Technologies

Alternatives		Technologies Included	Waste Site Group: Retention Basins	Sludge Trenches	Fuel Storage Basin Trenches	Process Effluent Trenches	Pluto Cribs	Decon Cribs/ French Drains	Seal Pit Cribs	Pipelines	Burial Grounds	D&D Facilities
No Action	SS-1 SW-1	None										X
Institutional Controls	SS-2 SW-2	Deed Restrictions							X			
		Groundwater Monitoring							X			
Containment	SS-3 SW-3	Surface Water Controls						X		X	X	
		Modified RCRA Barrier						X		X	X	
		Deed Restrictions						X		X	X	
		Groundwater Monitoring						X		X	X	
Removal, Disposal	SS-4 SW-4	Removal	X	X	X	X	X	X		X	X	
		Disposal	X	X	X	X	X	X		X	X	
In Situ Treatment	SS-8A	Surface Water Controls		X		X	X	X				
		In Situ Vitrification		X		X	X	X				
		Groundwater monitoring		X		X	X	X				
		Deed restrictions		X		X	X	X				
	SS-8B	Void Grouting								X		
		Modified RCRA Barrier								X		
		Surface Water Controls								X		
		Deed Restrictions								X		
		Groundwater Monitoring								X		
	SW-7	Dynamic Compaction									X	
		Modified RCRA Barrier									X	
		Surface Water Controls									X	
		Groundwater Monitoring									X	
		Deed Restrictions									X	
Removal, Treatment, Disposal	SS-10	Removal	X	X	X	X	X	X		X		
		Thermal Desorption										
		Soil Washing	X	X	X	X	X	X		X		
		Disposal	X	X	X	X	X	X		X		
	SW-9	Removal									X	
		Thermal Desorption									X	
		Compaction									X	
		ERDF Disposal									X	

Note:

X - Technology applies to this Waste Site Group
blank - Technology does not apply to this Waste Site Group
D&D - Decontaminated and Decommissioned
RCRA - Resource Conservation and Recovery Act
ERDF - Environmental Restoration Disposal Facility

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Table 5-2 Comparison of Waste Site Groups to Remedial Alternatives (page 1 of 3)

Waste Site Group		Retention Basin	Process Effluent Trench	Sludge Trench
Alternative	**Applicability Criteria and Enhancements**	**Are Applicability Criteria and Enhancements Met?**		
No Interim Action				
SS-1	Criterion: • Has site been effectively addressed in the past	No	No	No
Institutional Controls				
SS-2 SW-2	Criterion: • Contaminants < PRG	No	No	No
Containment				
SS-3 SW-3	Criteria: • Contaminants > PRG	Yes	Yes	Yes
	• Contaminants < reduced infiltration rate concentrations	No	No	No
Removal/Disposal				
SS-4 SW-4	Criterion: • Contaminants > PRG	Yes	Yes	Yes
In Situ Treatment				
SS-8A	Criteria: • Contaminants > PRG	Yes	Yes	Yes
	• Contamination < 5.8 m in depth	No	Yes	Yes
SS-8B	Criteria: • Contaminants > PRG	NA	NA	NA
	• Contaminants < reduced infiltration rate concentrations	NA	NA	NA
SW-7	Criteria: • Contaminants > PRG	NA	NA	NA
	• Contaminants < reduced infiltration rate concentrations	NA	NA	NA
Removal/Treatment/Disposal				
SS-10	Criterion: • Contaminants > PRG	Yes	Yes	Yes
	Enhancements: • Organic contaminants (if yes, thermal desorption must be included in the treatment system)	No	No	No
	• Percentage of contaminated volume less than twice the PRG for cesium-137.	67%	0%	67%
SW-9	Criterion: • Contaminants > PRG	NA	NA	NA
	Enhancement: • Organic contaminants	NA	NA	NA

Table 5-2 Comparison of Waste Sites to Remedial Alternatives (page 2 of 3)

Waste Site Group		Fuel Storage Basin Trench	Pluto Crib	Seal Pit Crib
Alternative	**Applicability Criteria and Enhancements**	**Are Applicability Criteria and Enhancements Met?**		
No Interim Action				
SS-1	Criterion: • Has site been effectively addressed in the past	No	No	No
Institutional Controls				
SS-2 SW-2	Criterion: • Contaminants < PRG	No	No	Yes
Containment				
SS-3 SW-3	Criteria: • Contaminants > PRG	Yes	Yes	NA
	• Contaminants < reduced infiltration rate concentrations	No	No	NA
Removal/Disposal				
SS-4 SW-4	Criterion: • Contaminants > PRG	Yes	Yes	NA
In Situ Treatment				
SS-8A	Criteria: • Contaminants > PRG	Yes	Yes	NA
	• Contamination < 5.8 m in depth	No	Yes	NA
SS-8B	Criteria: • Contaminants > PRG	NA	NA	NA
	• Contaminants < reduced infiltration rate concentrations	NA	NA	NA
SW-7	Criteria: • Contaminants > PRG	NA	NA	NA
	• Contaminants < reduced infiltration rate concentrations	NA	NA	NA
Removal/Treatment/Disposal				
SS-10	Criterion: • Contaminants > PRG	Yes	Yes	NA
	Enhancements: • Organic contaminants (if yes, thermal desorption must be included in the treatment system)	No	No	NA
	• Percentage of contaminated volume less than twice the PRG for cesium-137.	100%	100%	NA
SW-9	Criterion: • Contaminants > PRG	NA	NA	NA
	Enhancement: • Organic contaminants	NA	NA	NA

Table 5-2 Comparison of Waste Sites to Remedial Alternatives (page 3 of 3)

Waste Site Group		Pipeline	Burial Grounds	Decontamination and Decommissioning
Alternative	**Applicability Criteria and Enhancements**	**Are Applicability Criteria and Enhancements Met?**		
No Interim Action				
SS-1	Criterion: • Has site been effectively addressed in the past	No	No	Yes
Institutional Controls				
SS-2 SW-2	Criterion: • Contaminants < PRG	No	No	NA
Containment				
SS-3 SW-3	Criteria: • Contaminants > PRG	Yes	Yes	NA
	• Contaminants < reduced infiltration rate concentrations	Yes	Yes	NA
Removal/Disposal				
SS-4 SW-4	Criterion: • Contaminants > PRG	Yes	Yes	NA
In Situ Treatment				
SS-8A	Criteria: • Contaminants > PRG	NA	NA	NA
	• Contamination < 5.8 m in depth	NA	NA	NA
SS-8B	Criteria: • Contaminants > PRG	Yes	NA	NA
	• Contaminants < reduced infiltration rate concentrations	Yes	NA	NA
SW-7	Criteria: • Contaminants > PRG	NA	Yes	NA
	• Contaminants < reduced infiltration rate concentrations	NA	Yes	NA
Removal/Treatment/Disposal				
SS-10	Criterion: • Contaminants > PRG	NA	NA	NA
	Enhancements: • Organic contaminants (if yes, thermal desorption must be included in the treatment system)	NA	NA	NA
	• Percentage of contaminated volume less than twice the PRG for cesium-137.	NA	NA	NA
SW-9	Criterion: • Contaminants > PRG	NA	Yes	NA
	Enhancement: • Organic contaminants	NA	Yes	NA

NA - Not Applicable   PRG - Preliminary Remediation Goals

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Table 5-3 Detailed Analysis - Containment Alternative (SS-3/SW-3) (page 1 of 4)

OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	dummy decontamination cribs/french drains, pipelines, burial grounds
Will risk be at acceptable levels?	Yes. Risk is at acceptable levels by elimination of potential pathways through installation of an engineered barrier. The engineered barrier directly eliminates exposure pathways to human and ecological receptors. SS-3: Constituent concentrations are below levels which could impact groundwater under the reduced infiltration allowed by the barrier based on evaluation of constituent concentrations. SW-3: Constituent concentrations are assumed to be below levels which could impact groundwater under the reduced infiltration allowed by the barrier.
Timeframe to achieve acceptable levels?	Acceptable risk levels are achieved at the completion of the remedial action. The duration of the remedial action is estimated, based on the representative site for a given group, as follows: dummy decontamination cribs/french drains: 0.1 yrs pipelines: 2.4 yrs outfall structures: 0.1 yrs burial grounds: 0.1 yrs
Will the alternative pose any unacceptable short-term or cross-media impacts?	No cross-media impacts will be introduced by the alternative. Workers will not be exposed to the contaminants during implementation. Risks to workers during implementation can be minimized through engineering controls and proper health and safety protocols. Short-term impacts of adjacent habitat is outweighed by the long-term benefits. Short term risks to humans is low to medium, to ecological receptors is medium.

COMPLIANCE WITH ARAR	dummy decontamination cribs/french drains, pipelines, burial grounds
What are the potential ARAR?	1. Chemical-specific ARAR listed in Tables 2.2 and 2.3. 2. Location-specific ARAR listed in Tables 2.5 and 2.6. 3. Action-specific ARAR listed in Tables 2.8 and 2.9.
Will the potential ARAR listed above be met? How?	1. Yes. Chemical-specific ARAR will be met by meeting RAO and eliminating exposure pathways. 2. Yes. Location-specific ARAR can be met through proper planning and scheduling. 3. Yes. Action-specific ARAR are met through appropriate design and operation. The actions will be designed and operated to be compliant with the ARAR.
Basis for waivers?	No waivers are necessary.
What are the potential TBC?	1. Chemical-specific TBC listed in Table 2.4. 2. Location-specific TBC listed in Table 2.7. 3. Action-specific TBC listed in Table 2.10.
Is the alternative consistent with the TBC listed above?	1. Yes. Alternative is consistent with chemical specific TBC. The PRG are developed to comply with TBC. 2. Yes. Alternative is consistent with location specific TBC. 3. Yes. Action-specific TBC are consistent with action. The actions will be designed and operated to be compliant with the TBC.

**Table 5-3 Detailed Analysis - Containment Alternative (SS-3/SW-3)
(page 2 of 4)**

LONG-TERM EFFECTIVENESS AND PERMANENCE	dummy decontamination cribs/french drains, pipelines, burial grounds
What is the magnitude of the remaining risk?	Exposure pathways are eliminated, therefore, eliminating any potential risk.
What remaining sources of risk can be identified?	All sources remain. However, all potential exposure pathways are eliminated.
What is the likelihood that the technologies will meet performance needs?	A barrier is an established technology that will meet or exceed performance requirements.
What type, degree, and requirement of long-term management is required?	Long-term post closure monitoring of the barrier is required. In addition, groundwater surveillance monitoring will be conducted as part of the groundwater operable unit.
What O&M functions must be performed?	Repair and maintenance of the engineered barrier.
What difficulties may be associated with long-term O&M?	None.
What is the potential need for replacement of technical components?	A potential exists for a small degree of settlement which may result in the disruption of the engineered barrier. Routine inspections and barrier maintenance should keep this potential at a minimum.
What is the magnitude of risk should the remedial action need replacement?	Minimal, since there is no exposure to the contaminated waste.
What is the degree of confidence that controls can adequately handle potential problems?	Control technologies implemented under this alternative are judged to be highly reliable.
What are the uncertainties associated with land disposal of residuals and untreated wastes.	Not applicable.

REDUCTION OF TOXICITY, MOBILITY, OR VOLUME	dummy decontamination cribs/french drains, pipelines, burial grounds
Does the treatment process address the principal threats?	No treatment proposed. However, an engineered barrier addresses the principal threats to human health, ecosystems, and groundwater by eliminating potential exposure pathways.
Are there any special requirements for the treatment process?	No treatment proposed.
What portion of the contaminated material is treated/destroyed?	No contaminants are treated or destroyed.
To what extent is the total mass of toxic contaminants reduced?	Long-term reduction caused by natural degradation of radionuclides.
To what extent is the mobility of contaminants reduced?	Contaminants are effectively immobilized through reduction in hydraulic infiltration.
To what extent is the volume of contaminated media reduced?	None. No treatment proposed.
To what extent are the effects of the treatment irreversible?	No treatment proposed.
What are the quantities of residuals and characteristics of the residual risk?	None. No residuals are present.
What risks do treatment of residuals pose?	None. No residuals are present.
Is treatment used to reduce inherent hazards posed by principal threats at the site?	No treatment proposed.

Table 5-3 Detailed Analysis - Containment Alternative (SS-3/SW-3) (page 3 of 4)

SHORT-TERM EFFECTIVENESS	dummy decontamination cribs/french drains, pipelines, burial grounds
What are the risks to the community during remedial actions, and how will they be mitigated?	Potential for releases of fugitive dusts. Appropriate engineering controls and contingency plans will be developed and implemented during the barrier installation. No contaminated material will be exposed during installation. Community risks will be negligible.
What risks remain to the community that cannot be readily controlled?	None.
What are the risks to the workers, and how will they be mitigated?	Risks due to exposure or accident. Potential for releases of fugitive dusts during barrier construction. Workers are not exposed to contaminated materials during implementation. Risks can be minimized by implementing appropriate engineering controls and health and safety procedures. Short term risk is low to medium.
What risks remain to the workers that cannot be readily controlled?	None.
What environmental impacts are expected with the construction and implementation of the alternative?	Fugitive dust releases could possibly affect outlying environment but can be controlled through proper operating procedures. Remedial activities can be scheduled to accommodate nesting or roosting species. Soil excavation may impact terrestrial species where activities near the river may impact aquatic and wetland species. Short term risk is medium.
What are the impacts that cannot be avoided should the alternative be implemented?	None.
How long until remedial response objectives are achieved?	All RAO are met upon completion of barrier installation.

IMPLEMENTABILITY	dummy decontamination cribs/french drains, pipelines, burial grounds
What difficulties and uncertainties are associated with construction?	Location confidence is low for some sites. Investigations may be required in order to locate and plan extent of barrier. Outfall Structures: Barrier construction may be difficult on steeply sloping terrain such as near the Columbia River. Structures will need to be removed or backfilled prior to construction.
What is the likelihood that technical problems will lead to schedule delays?	Minimal. A barrier is proven technology. Proper planning can prevent schedule delays that may be encountered if location investigation is necessary.
What likely future remedial actions are anticipated?	None.
What risks of exposure exist should monitoring be insufficient to detect failure?	Barrier failure could result in hydraulic infiltration through the site. Impact to groundwater possible, although risk is less than present. Human and ecosystem exposure is unlikely.
What activities are proposed which require coordination with other agencies?	Long-term deed restrictions will require coordination with state groundwater agencies and with local zoning authorities.
Are adequate treatment, storage capacity, and disposal services available?	Not applicable.
Are necessary equipment and specialists available?	Yes. General earthwork construction equipment and barrier materials are required and are readily available. Construction materials can be obtained from onsite sources. Barrier design and construction specialists are available.
Are technologies under consideration generally available and sufficiently demonstrated or will they require further development before they can be applied at the site?	Yes. Deed restrictions and groundwater surveillance monitoring have been effective at other locations. Installation of a surface barrier is an established technology. Hanford-specific designs are currently being implemented at the 200-BP-1 Operable Unit.
Will more than one vendor be available to provide a competitive bid?	Yes. Several general earthwork and barrier construction contractors exist locally.

Table 5-3 Detailed Analysis - Containment Alternative (SS-3/SW-3) (page 4 of 4)

COST	CAPITAL	O&M	PRESENT WORTH
dummy decontamination cribs/french drains	$401,000 •Includes: Installation of an engineered barrier.	$125,000 •Includes: maintenance and repair of the engineered barrier	$454,000
pipelines	$47,000,000 •Includes: Installation of an engineered barrier.	$21,800,000 •Includes: maintenance and repair of the engineered barrier	$54,600,000
burial grounds	$1,220,000 •Includes: Installation of an engineered barrier.	$514,000 •Includes: maintenance and repair of the engineered barrier	$1,450,000

ARAR - applicable, relevant and appropriate requirements
TBC - to-be-considered
O&M - operation and maintenance
RAO - remedial action objectives
PRG - preliminary remediation goals

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Table 5-4 Detailed Analysis - Removal/Disposal Alternative (SS-4/SW-4) (page 1 of 6)

OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
Will risk be at acceptable levels?	Yes. Risk is at acceptable levels through removal of the contaminated material from the site (i.e., elimination of the source). Human health and ecological exposure pathways are eliminated by excavation. Impact to groundwater is eliminated by removal of contaminated material exceeding PRG. Contaminated material is transferred to a common disposal facility (i.e., ERDF or W-025).
Timeframe to achieve acceptable levels?	Acceptable risk levels will be achieved at the completion of the remedial action. The duration of the remedial action is estimated, based on the representative site for a given group, as follows: retention basins: 1.4 yrs sludge trenches: 0.1 yrs fuel storage basin trenches: 0.2 yrs process effluent trenches: 0.5 yrs pluto cribs: 0.1 yrs dummy decontamination crib/french drain: 0.1 yrs pipelines: 2.4 yrs outfall structures: 0.1 yrs burial grounds: 0.1 yrs
Will the alternative pose any unacceptable short-term or cross-media impacts?	No cross-media impacts are introduced by the alternative. Worker exposure to the contaminants can be controlled during the excavation through development and implementation of appropriate engineering controls and proper health and safety protocols. Short-term impacts of adjacent habitat is outweighed by the long-term benefits. Short term risks to humans is medium and to ecological receptors is medium.

COMPLIANCE WITH ARAR	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
What are the potential ARAR?	1. Chemical-specific ARAR listed in Tables 2.2 and 2.3. 2. Location-specific ARAR listed in Tables 2.5 and 2.6. 3. Action-specific ARAR listed in Tables 2.8 and 2.9.
Will the potential ARAR listed above be met? How?	1. Yes. Chemical-specific ARAR will be met. No constituents will be present in soil which exceed PRG. The PRG are developed to comply with ARAR. 2. Yes. Location-specific ARAR can be met through proper planning and scheduling. 3. Yes. Action-specific ARAR are met through appropriate design and operation. The actions will be designed and operated to be compliant with the ARAR.
Basis for waivers?	No waivers are necessary.
What are the potential TBC?	1. Chemical-specific TBC listed in Table 2.4. 2. Location-specific TBC listed in Table 2.7. 3. Action-specific TBC listed in Table 2.10.
Is the alternative consistent with the TBC listed above?	1. Yes. Alternative is consistent with chemical-specific TBC. No constituents will be present in soil which exceed PRG. The PRG are developed to comply with TBC. 2. Yes. Alternative is consistent with location specific TBC. 3. Yes. Action-specific TBC are consistent with action. The actions will be designed and operated to be compliant with the TBC.

Table 5-4 Detailed Analysis - Removal/Disposal Alternative (SS-4/SW-4) (page 2 of 6)

LONG-TERM EFFECTIVENESS AND PERMANENCE	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
What is the magnitude of the remaining risk?	None. Contaminated material exceeding PRG are removed and disposed therefore eliminating source at the waste site.
What remaining sources of risk can be identified?	None.
What is the likelihood that the technologies will meet performance needs?	Excavation and disposal are established technologies that meet or exceed performance requirements.
What type, degree, and requirement of long-term management is required?	None necessary at the excavation site. All long-term management is associated with the disposal facility.
What O&M functions must be performed?	None necessary at the1230Xexcavation All long-term O&M is associated with the disposal facility.
What difficulties may be associated with long-term O&M?	Not applicable.
What is the potential need for replacement of technical components?	Not applicable.
What is the magnitude of risk should the remedial action need replacement?	Not applicable.
What is the degree of confidence that controls can adequately handle potential problems?	Not applicable.
What are the uncertainties associated with land disposal of residuals and untreated wastes.	The contaminated material is transferred to the disposal facility. Waste acceptance applicability criteria and design of the facility is being developed in consideration of receiving Hanford Site contaminated material.

REDUCTION OF TOXICITY, MOBILITY, OR VOLUME	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
Does the treatment process address the principal threats?	No treatment proposed.
Are there any special requirements for the treatment process?	No treatment proposed.
What portion of the contaminated material is treated/destroyed?	None, all contaminants are removed and disposed at a common disposal facility.
To what extent is the total mass of toxic contaminants reduced?	Long-term reduction caused by natural degradation of radionuclides.
To what extent is the mobility of contaminants reduced?	No reduction in mobility of toxic contaminants.
To what extent is the volume of contaminated media reduced?	No reduction in volume of contaminated media.
To what extent are the effects of the treatment irreversible?	No treatment proposed.
What are the quantities of residuals and characteristics of the residual risk?	None. No residuals are present.
What risks do treatment of residuals pose?	None. No residuals are present.
Is treatment used to reduce inherent hazards posed by principal threats at the site?	No treatment proposed.

**Table 5-4 Detailed Analysis - Removal/Disposal Alternative (SS-4/SW-4)
(page 3 of 6)**

SHORT-TERM EFFECTIVENESS	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
What are the risks to the community during remedial actions, and how will they be mitigated?	Potential for releases of fugitive dusts during excavation. Appropriate engineering controls and contingency plans can be developed and implemented during the excavation and disposal.
What risks remain to the community that cannot be readily controlled?	None.
What are the risks to the workers, and how will they be mitigated?	Risks due to exposure or accident. Potential for releases of fugitive dusts during excavation. Risks can be controlled by implementing appropriate engineering controls and health and safety procedures. Short term risk is medium.
What risks remain to the workers that cannot be readily controlled?	SS-4: None, contaminants are known and will be mitigated through excavation of the contaminated material. SW-4: Minimal, contaminants are not known, however, excavation of the contaminated material should mitigate any potential risks.
What environmental impacts are expected with the construction and implementation of the alternative?	Fugitive dust releases could possibly affect outlying environment but can be controlled through proper operating procedures. Remedial activities can be scheduled to accommodate nesting or roosting species. Soil excavation will impact terrestrial species where activities near the river may impact aquatic and wetland species. Short term risk is medium.
What are the impacts that cannot be avoided should the alternative be implemented?	None.
How long until remedial response objectives are achieved?	All RAO are met upon completion of remedial alternative.

IMPLEMENTABILITY	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
What difficulties and uncertainties are associated with construction?	The extent of contamination is uncertain but will be delineated during excavation. SW-4: Uncertainties exist concerning the nature of buried wastes and the problems with encountering unexpected materials.
What is the likelihood that technical problems will lead to schedule delays?	Delays not likely. No adaptations to excavation technology are expected. There is some uncertainty on availability and schedule of disposal facilities.
What likely future remedial actions are anticipated?	None.
What risks of exposure exist should monitoring be insufficient to detect failure?	Removal does not require post closure monitoring.
What activities are proposed which require coordination with other agencies?	None.
Are adequate treatment, storage capacity, and disposal services available?	Yes. Maximum capacity at the W-025 facility is 25,000 yd^3, available in 1994. The ERDF capacity is 4.3 million yd^3, available in 1996. Remedial action will not be implemented until disposal is available.
Are necessary equipment and specialists available?	Yes. General earthwork construction equipment is required and is readily available. Excavation and analytical specialists are required and are available. Specialized analytical equipment may be required and is available.

Table 5-4 Detailed Analysis - Removal/Disposal Alternative (SS-4/SW-4) (page 4 of 6)

IMPLEMENTABILITY	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
Are technologies under consideration generally available and sufficiently demonstrated or will they require further development before they can be applied at the site?	Yes. Removal and disposal are developed technologies. Excavation of the 116-F-4 pluto crib has been completed demonstrating many of the technologies to be used. Excavation of the 118-B-1 burial ground will be conducted in the summer of 1994 to demonstrate the ability to excavate buried waste.
Will more than one vendor be available to provide a competitive bid?	Yes. Several general earthwork contractors exist locally. Many vendors are also available to supply monitoring equipment.

Table 5-4 Detailed Analysis - Removal/Disposal Alternative (SS-4/SW-4) (page 5 of 6)

COST	CAPITAL	O&M	PRESENT WORTH
retention basins	$102,000,000 •Includes: Removal of the contaminated material and site restoration Transportation of the contaminated material to a common disposal facility	$0 •Includes: None	$96,000,000
sludge trenches	$1,750,000 •Includes: Removal of the contaminated material and site restoration Transportation of the contaminated material to a common disposal facility	$0 •Includes: None	$1,670,000
fuel storage basin trenches	$4,690,000 •Includes: Removal of the contaminated material and site restoration Transportation of the contaminated material to a common disposal facility	$0 •Includes: None	$4,470,000
process effluent trenches	$16,500,000 •Includes: Removal of the contaminated material and site restoration Transportation of the contaminated material to a common disposal facility	$0 •Includes: None	$15,700,000
pluto cribs	$277,000 •Includes: Removal of the contaminated material and site restoration Transportation of the contaminated material to a common disposal facility	$0 •Includes: None	$267,000
dummy decontamination crib/french drain	$295,000 •Includes: Removal of the contaminated material and site restoration Transportation of the contaminated material to a common disposal facility	$0 •Includes: None	$283,000
pipelines	$36,100,000 •Includes: Removal of the contaminated material and site restoration Transportation of the contaminated material to a common disposal facility	$0 •Includes: None	$32,900,000

Table 5-4 Detailed Analysis - Removal/Disposal Alternative (SS-4/SW-4) (page 6 of 6)

COST	CAPITAL	O&M	PRESENT WORTH
burial grounds	$2,500,000 •Includes: Removal of the contaminated material and site restoration Transportation of the contaminated material to a common disposal facility	$0 •Includes: None	$2,380,000

PRG - preliminary remediation goals
RAO - remedial action objective
ARAR - applicable, relevant and appropriate requirements
ERDF - Environmental Restoration Disposal Facility
O&M - operations and maintenance
TBC - to-be-considered

Table 5-5 Detailed Analysis - In Situ Treatment Alternative (SS-8A/SS-8B/SW-7) (page 1 of 8)

OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	sludge trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
Will risk be at acceptable levels?	Yes. Risk is at acceptable levels by elimination of potential pathways through in situ treatment (i.e., vitrification). SS-8A: Yes. Risk is at acceptable levels by elimination of human health and ecological exposure pathways. In situ vitrification of the contaminated material which is overlain by 1 m of clean fill directly eliminates exposure pathways to human and ecological receptors. Constituent concentrations are at levels which are protective of groundwater. SS-8B: Yes. Risk is at acceptable levels by elimination of potential exposure pathways through installation of an engineered barrier over areas which have contaminated material. Grouting of the effluent pipeline effectively immobilizes any contaminated sludge which may be present. Constituent concentrations are below levels which would impact groundwater under the reduced infiltration allowed by the engineered barrier based on evaluation of constituent concentrations. SW-7: Yes. Risk is at acceptable levels by elimination of potential exposure pathways through installation of an engineered barrier over areas which have contaminated material. Constituent concentrations are assumed to be below levels which would impact groundwater under the reduced infiltration allowed by the barrier. Additional benefits are gathered from mobility reduction of contaminants due to dynamic compaction.
Timeframe to achieve acceptable levels?	Acceptable risk levels will be achieved at the completion of the remedial action. The duration of the remedial action is estimated, based on the representative site for a given group, as follows: sludge trenches: 0.4 yrs process effluent trenches: 3.8 yrs pluto cribs: 0.1 yrs dummy decontamination crib/french drain: 0.1 yrs pipelines: 0.2 yrs burial grounds: 0.1 yrs
Will the alternative pose any unacceptable short-term or cross-media impacts?	No cross-media impacts are introduced by the alternative. Workers will not be exposed to the contaminants during implementation. Risks to workers during implementation can be minimized through engineering controls and proper health and safety protocols. Short-term impacts of adjacent habitat is outweighed by the long-term benefits. Short term risk to humans is low to medium, and to ecological receptors is medium.

Table 5-5 Detailed Analysis - In Situ Treatment Alternative (SS-8A/SS-8B/SW-7) (page 2 of 8)

COMPLIANCE WITH ARAR	sludge trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
What are the potential ARAR?	1. Chemical-specific ARAR listed in Tables 2.2 and 2.3. 2. Location-specific ARAR listed in Tables 2.5 and 2.6. 3. Action-specific ARAR listed in Tables 2.8 and 2.9.
Will the potential ARAR listed above be met? How?	1. Yes. Chemical specific ARAR will be met by meeting RAO and eliminating exposure pathways. 2. Yes. Location-specific ARAR can be met through proper planning and scheduling. 3. Yes. Action-specific ARAR are met through appropriate design and operation. The actions will be designed and operated to be compliant with the ARAR.
Basis for waivers?	No waivers are necessary.
What are the potential TBC?	1. Chemical-specific TBC listed in Table 2.4. 2. Location-specific TBC listed in Table 2.7. 3. Action-specific TBC listed in Table 2.10.
Is the alternative consistent with the TBC listed above?	1. Yes. Alternative is consistent with chemical-specific TBC. No constituents will be present in soil which exceed PRG. The PRG are developed to comply with TBC. 2. Yes. Alternative is consistent with location-specific TBC. 3. Yes. Action-specific TBC are consistent with action. The actions will be designed and operated to be compliant with the TBC.

Table 5-5 Detailed Analysis - In Situ Treatment Alternative (SS-8A/SS-8B/SW-7) (page 3 of 8)

LONG-TERM EFFECTIVENESS AND PERMANENCE	sludge trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
What is the magnitude of the remaining risk?	Exposure pathways are eliminated, therefore, eliminating any potential risk.
What remaining sources of risk can be identified?	All sources remain. However, all exposure pathways are eliminated.
What is the likelihood that the technologies will meet performance needs?	SS-8A: In situ vitrification is an innovative technology that should be effective in meeting performance requirements. SS-8B: Void grouting and installation of an engineered barrier are established technologies which will meet or exceed performance requirements. SW-7: An engineered barrier is an established technology that will meet or exceed performance requirements. Dynamic compaction involves a demonstrated technology capable of meeting performance requirements.
What type, degree, and requirement of long-term management is required?	Long-term deed restrictions is required. In addition, groundwater surveillance monitoring will be conducted as part of the groundwater operable unit. SS-8B: Long-term post closure monitoring of the engineered barrier is required. SW-7: Long-term post closure monitoring of the engineered barrier is required.
What O&M functions must be performed?	SS-8A: Maintenance of soil cover overlying the vitrified material (for shielding o provide long-term protection of human health and the environment by eliminating external radiation exposure due to radionuclides left in situ) and operation and maintenance of the in situ vitrification system. SS-8B and SW-7: Repair and maintenance of the engineered barrier.
What difficulties may be associated with long-term O&M?	None.
What is the potential need for replacement of technical components?	SS-8B and SW-7: A potential exists for a small degree of settlement which may result in the disruption of the engineered barrier. Routine inspections and barrier maintenance should keep this potential to a minimum.
What is the magnitude of risk should the remedial action need replacement?	Minimal, since there is no exposure to the contaminated material.
What is the degree of confidence that controls can adequately handle potential problems?	Control technologies implemented under this alternative are judged to be highly reliable.
What are the uncertainties associated with land disposal of residuals and untreated wastes.	Not applicable.

Table 5-5 Detailed Analysis - In Situ Treatment Alternative (SS-8A/SS-8B/SW-7) (page 4 of 8)

REDUCTION OF TOXICITY, MOBILITY, OR VOLUME	sludge trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
Does the treatment process address the principal threats?	SS-8A: Yes. Contaminants are immobilized and principle exposure pathways are eliminated. SS-8B: Yes. Grouting of pipelines reduces mobilization and leachability of wastes. Principle exposure pathways are eliminated through installation of the engineered barrier. SW-7: Yes. Dynamic compaction enhances the barrier effectiveness and reduces mobility of wastes. Principle exposure pathways are eliminated through installation of the engineered barrier.
Are there any special requirements for the treatment process?	SS-8A: A treatability study performed at the 116-B-6A crib area encountered a depth limitation of 4.3 m (14 ft), possibly due to the presence of a cobble layer. The EPA documentation states that ISV is effective to a maximum depth of 5.8 m (19 ft). Also, 4,000 Amps of electricity are required at the beginning of the melt. SS-8B: Video survey of lines should be conducted prior to grouting. SW-7: Delineation of the extent of buried wastes required to verify assumptions. Verification that dynamic compaction is effective for the type and extent of wastes found at a particular site is also required.
What portion of the contaminated material is treated/destroyed?	SS-8A: All of the material to the maximum melt depth is treated, however, only organics are destroyed. SS-8B: Sludges within the pipelines may be treated through stabilization, none of the material is destroyed. SW-7: All material is compacted, none of the material is destroyed.
To what extent is the total mass of toxic contaminants reduced?	Long-term reduction caused by natural degradation of radionuclides.
To what extent is the mobility of contaminants reduced?	SS-8A: Contaminants are effectively immobilized by stabilizing the contaminants in the glass melt. Hydraulic infiltration is temporarily reduced and mobilization is eliminated. SS-8B: Contaminants are effectively immobilized through the void grouting and reduction in hydraulic infiltration in contaminated soil areas where the engineered barrier is installed. SW-7: Contaminants are effectively immobilized through reduction in hydraulic infiltration by compaction and installation of the engineered barrier.
To what extent is the volume of contaminated media reduced?	SS-8A/8B: In situ vitrification reduces volume by 30%. SW-7: Dynamic compaction has been shown to reduce contaminated volume by approximately 10% to 15%.
To what extent are the effects of the treatment irreversible?	SS-8A: In situ vitrification is an irreversible process. SS-8B: Grouting can be reversed with mechanical methods. An engineered barrier can be removed. SW-7: Dynamic compaction can be reversed with mechanical methods. An engineered barrier can be removed.
What are the quantities of residuals and characteristics of the residual risk?	SS-8A: Minimal quantities of residuals from offgas treatment including condensate and contaminated filters. SS-8B and SW-7: No treatment residuals are produced.
What risks do treatment of residuals pose?	SS-8A: None. Residuals will be disposed at a common disposal facility. SS-8B and SW-7: None. No residuals are produced.
Is treatment used to reduce inherent hazards posed by principal threats at the site?	Yes. The principle exposure pathways are eliminated.

Table 5-5 Detailed Analysis - In Situ Treatment Alternative (SS-8A/SS-8B/SW-7) (page 5 of 8)

SHORT-TERM EFFECTIVENESS	sludge trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
What are the risks to the community during remedial actions, and how will they be mitigated?	SS-8A: Potential for releases of fugitive dusts and gases during treatment. Appropriate engineering controls and contingency plans will be developed and implemented. SS-8B and SW-7: Potential for releases of fugitive dusts during treatment. Appropriate engineering controls and contingency plans will be developed and implemented.
What risks remain to the community that cannot be readily controlled?	None.
What are the risks to the workers, and how will they be mitigated?	Risks due to exposure or accident. Potential for releases of fugitive dusts during remedial alternative. Risks can be minimized by implementing appropriate engineering controls and health and safety procedures. Short term risks are low to medium.
What risks remain to the workers that cannot be readily controlled?	SS-8A and 8B: None. SW-7: Contaminants are unknown, therefore, a potential risk exists due to this uncertainty.
What environmental impacts are expected with the construction and implementation of the alternative?	Fugitive dust releases could possibly affect outlying environment but can be controlled through proper operating procedures. Remedial activities can be scheduled to accommodate nesting or roosting species. Soil excavation will impact terrestrial species where activities near the river may impact aquatic and wetland species. Short term risk is medium. Soil excavation will impact terrestrial species where activities near the river may impact aquatic and wetland species. Short term risk is medium.
What are the impacts that cannot be avoided should the alternative be implemented?	None.
How long until remedial response objectives are achieved?	All RAO are met upon completion of remedial alternative.

Table 5-5 Detailed Analysis - In Situ Treatment Alternative (SS-8A/SS-8B/SW-7) (page 6 of 8)

IMPLEMENTABILITY	sludge trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
What difficulties and uncertainties are associated with construction?	SS-8A: Investigation(s) may be required in order to locate the area proposed for ISV. In addition, soil particle sizes may vary from site to site. Existence of cobble layers and structural members may affect performance. The presence of excessive moisture or groundwater can limit the economic practicality of ISV due to the time and energy required to drive off the water. Soils with low alkaline content may be unable to effectively carry a charge and thereby diminish the applicability of ISV (EPA 1992). Large quantities of combustible liquids or solids may increase the gas production rate beyond the capacity of the offgas system. In addition, the presence of metals in the soil can result in a conductive path that would lead to electrical shorting between electrodes. SS-8B: Investigation(s) may be required in order to locate and plan the extent of the barrier. The integrity (groutability) of the pipelines is uncertain and should be confirmed by investigation. SW-7: Dynamic compaction has been successful at other sites. Uncertainties exist due to variations in type of waste, unknown burial ground contents. Investigation(s) may be required in order to locate and plan the extent of the barrier.
What is the likelihood that technical problems will lead to schedule delays?	SS-8A: Adaptations to construction technology may be necessary to enable different waste site types to be treated. SS-8B: Minimal. Void grouting and a barrier are proven technology. Proper planning can prevent schedule delays that may be encountered if investigation is necessary. SW-7: Minimal. Dynamic compaction and a barrier are proven technology. Proper planning can prevent schedule delays that may be encountered if location investigation is necessary.
What likely future remedial actions are anticipated?	None.
What risks of exposure exist should monitoring be insufficient to detect failure?	SS-8A: Human and ecological exposure may occur through undetected failure of the soil cover. The stability of the glass matrix should be very effective in minimizing risk to human health and the environment. SS-8B and SW-7: Failure of the engineered barrier could result in hydraulic infiltration through the site.
What activities are proposed which require coordination with other agencies?	Long-term deed restrictions will require coordination with state groundwater agencies and with local zoning authorities.
Are adequate treatment, storage capacity, and disposal services available?	Not applicable.
Are necessary equipment and specialists available?	SS-8A: Yes. All necessary equipment and specialists are readily available. SS-8B: Yes. General earthwork construction equipment and barrier materials are required and are readily available. Grouting and barrier construction specialists are required and available. SW-7: Yes. General earthwork construction equipment and barrier materials are required and are readily available. A specialized tamper may need to be constructed. Dynamic compaction and barrier design and construction specialists are required and available.

Table 5-5 Detailed Analysis - In Situ Treatment Alternative (SS-8A/SS-8B/SW-7) (page 7 of 8)

IMPLEMENTABILITY	sludge trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
Are technologies under consideration generally available and sufficiently demonstrated or will they require further development before they can be applied at the site?	Yes. Deed restrictions and groundwater surveillance monitoring have been effective at other locations. SS-8A: In situ vitrification is an innovative technology but has been effectively demonstrated at a number of sites to immobilize contaminants and effectively reduce leaching. SS-8B: Grouting has been successfully implemented at construction sites. Modifications may be needed to apply the technology at pipeline sites. Surface barriers are established technologies. Hanford-specific designs are currently being implemented at the 200-BP-1 Operable Unit. SW-7: Dynamic compaction has been successfully implemented at other sites and tested at Hanford. Modifications may be needed to apply the technology at burial ground sites. Surface barriers are established technologies. Hanford-specific designs are currently being implemented at the 200-BP-1 Operable Unit.
Will more than one vendor be available to provide a competitive bid?	SS-8A: Geosafe is the exclusive vendor for DOE, however other vendors can supply ISV to DOE if available. SS-8B: Yes. Grouting, general earthwork, and barrier construction contractors exist locally. SW-7: Yes. Compaction, general earthwork, and barrier construction contractors exist locally.

Table 5-5 Detailed Analysis - In Situ Treatment Alternative (SS-8A/SS-8B/SW-7) (page 8 of 8)

COST	CAPITAL	O&M	PRESENT WORTH
sludge trenches	$3,610,000 •Includes: In situ vitrification equipment and installation	$2,290,000 •Includes: maintenance of the soil cover operation of in situ vitrification system	$5,630,000
process effluent trenches	$33,900,000 •Includes: In situ vitrification equipment and installation	$27,700,000 •Includes: maintenance of the soil cover operation of in situ vitrification system	$54,800,000
pluto cribs	$598,000 •Includes: In situ vitrification equipment and installation	$89,600 •Includes: maintenance of the soil cover operation of in situ vitrification system	$661,000
dummy decontamination crib/french drain	$632,000 •Includes: In situ vitrification equipment and installation	$113,000 •Includes: maintenance of the soil cover operation of in situ vitrification system	$715,000
pipelines	$7,040,000 •Includes: Installation of an engineered barrier. Grouting of the pipeline	$3,880,000 •Includes: maintenance and repair of the engineered barrier	$8,870,000
burial grounds	$1,430,000 •Includes: Installation of an engineered barrier. Dynamic soil compaction	$576,000 •Includes: maintenance and repair of the engineered barrier	$1,690,000

ARAR - applicable or relevant and appropriate requirements
TBC - to-be-considered
O&M - operation and maintenance
RAO - remedial action objectives
PRG - preliminary remediation goals

Table 5-6 Detailed Analysis - Removal/Treatment/Disposal Alternative (SS-10/SW-9) (page 1 of 8)

OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
Will risk be at acceptable levels?	Yes. Risk is at acceptable levels through removal of the contaminated material from the site (i.e., elimination of the source). Human health and ecological exposure pathways are eliminated by excavation. Impact to groundwater eliminated by removal of contaminated material exceeding PRG. Contaminated material is transferred to a common disposal facility (i.e., ERDF or W-025). SS-10: Additional benefits from the mass and volume reduction of contaminants due to soil washing. SW-9: Additional benefits are realized from the reduction in mass, mobility, and volume of contaminants due to thermal desorption and compaction.
Timeframe to achieve acceptable levels?	Acceptable risk levels are achieved at the completion of the remedial action. The duration of the remedial action is estimated, based on the representative site for a given group, as follows: retention basins: 3.2 yrs sludge trenches: 0.1 yrs fuel storage basin trenches: 0.3 yrs process effluent trenches: 0.6 yrs pluto cribs: 0.1 yrs dummy decontamination crib/french drain: 0.1 yrs pipelines: 2.5 yrs outfall structures: 0.1 yrs burial grounds: 0.1 yrs
Will the alternative pose any unacceptable short-term or cross-media impacts?	No cross-media impacts are introduced by the alternative. Worker exposure to the contaminants can be controlled during the excavation through development and implementation of appropriate engineering controls and proper health and safety protocols. Short term risk to humans is high and to ecological receptors is medium.

COMPLIANCE WITH ARAR	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
What are the potential ARAR?	1. Chemical-specific ARAR listed in Tables 2.2 and 2.3. 2. Location-specific ARAR listed in Tables 2.5 and 2.6. 3. Action-specific ARAR listed in Tables 2.8 and 2.9.
Will the potential ARAR listed above be met? How?	1. Yes. Chemical-specific ARAR will be met. No constituents will be present in soil which exceed PRG. The PRG are developed to comply with ARAR. 2. Yes. Location-specific ARAR can be met through proper planning and scheduling. 3. Yes. Action-specific ARAR are met through appropriate design and operation. The actions will be designed and operated to be compliant with the ARAR.
Basis for waivers?	No basis.
What are the potential TBC?	1. Chemical-specific TBC listed in Table 2.4. 2. Location-specific TBC listed in Table 2.7. 3. Action-specific TBC listed in Table 2.10.
Is the alternative consistent with the TBC listed above?	1. Yes. Alternative is consistent with chemical-specific TBC. No constituents will be present in soil which exceed PRG. The PRG are developed to comply with TBC. 2. Yes. Alternative is consistent with location-specific TBC. 3. Yes. Action-specific TBC are consistent with action. The actions will be designed and operated to be compliant with the TBC.

Table 5-6 Detailed Analysis - Removal/Treatment/Disposal Alternative (SS-10/SW-9) (page 2 of 8)

LONG-TERM EFFECTIVENESS AND PERMANENCE	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
What is the magnitude of the remaining risk?	None. Contaminated material exceeding PRG are removed, treated and disposed therefore eliminating the source at the waste site.
What remaining sources of risk can be identified?	None.
What is the likelihood that the technologies will meet performance needs?	Excavation, treatment, and disposal are established technologies that meet or exceed performance requirements. SS-10: Soil washing is an established technology; however, less proven than excavation, but should meet performance requirements under favorable circumstances. SW-9: Thermal desorption and compaction are established technologies that meet performance requirements.
What type, degree, and requirement of long-term management is required?	Treatment (i.e., soil washing or thermal desorption) of the contaminated material in the vicinity of the excavation site. All additional long-term management is associated with the disposal facility.
What O&M functions must be performed?	Treatment (i.e., soil washing or thermal desorption) of the contaminated material in the vicinity of the excavation site. All additional long-term O&M is associated with the disposal facility.
What difficulties may be associated with long-term O&M?	Not applicable.
What is the potential need for replacement of technical components?	Not applicable.
What is the magnitude of risk should the remedial action need replacement?	Not applicable.
What is the degree of confidence that controls can adequately handle potential problems?	Not applicable.
What are the uncertainties associated with land disposal of residuals and untreated wastes.	The contaminated material is transferred to a common disposal facility. Waste acceptance applicability criteria and design of the facility is being developed in consideration of receiving Hanford Site contaminated material.

Table 5-6 Detailed Analysis - Removal/Treatment/Disposal Alternative (SS-10/SW-9) (page 3 of 8)

REDUCTION OF TOXICITY, MOBILITY, OR VOLUME	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
Does the treatment process address the principal threats?	Yes. SS-10: Soil washing reduces the threats at sites with little or no cesium-137 associated with the cobbles or gravels, or at sandy sites where cesium-137 exists at levels that are treatable. SW-9: Thermal desorption reduces threats associated with volatile and semi-volatile organic compounds. Compaction reduces volume and leachability.
Are there any special requirements for the treatment process?	Yes. SS-10: Sites must contain cesium-137 below PRG in the gravels or cobbles and the cesium-137 concentrations cannot exceed twice the PRG for effective reduction in the two stage attrition scrubber. SW-9: Waste must be appropriately sized for the thermal desorption process and segregated for compaction.
What portion of the contaminated material is treated/destroyed?	SS-10: The soil washing includes size separation and a two stage attrition scrubber. A fraction of the contaminated materials can be treated by the two stage attrition scrubber. Contaminated but untreated cobbles are transported directly to the disposal facility. SW-9: Approximately 5% of contaminated materials are assumed to be treatable by thermal desorption, about 50% of desorbed organic constituents are destroyed. Approximately 90% of wastes are assumed to be treatable by compaction, none of the compacted constituents are destroyed.
To what extent is the total mass of toxic contaminants reduced?	Long-term reduction caused by natural degradation of radionuclides. The mass reduction at the disposal facility is discussed below. SS-10: Reduction in radionuclide concentrations associated with the soil fines (2mm to 0.25mm in size) may be achieved, reducing the mass of contaminated media. SW-9: Nearly all of the volatile and semi-volatile organic contaminants are reduced. No reduction in mass of inorganic contaminants is achieved.
To what extent is the mobility of contaminants reduced?	Mobility of constituents is eliminated at the waste site by removal. The mobility reduction at the disposal facility is achieved as follows: SW-9: Nearly all of the volatile and semi-volatile organic contaminants are rendered immobile. Mobility (leachability) of inorganic constituents are reduced by compaction.
To what extent is the volume of contaminated media reduced?	The percentage suitable for soil washing was determined based on an evaluation of cesium-137 concentrations with respect to depth and treatment limitations. Based on the extent of cesium-137 contamination relative to total extent of contamination, the percentage was estimated. Retention basins, sludge trenches, dummy decontamination cribs/french drains: 67% of the contaminated soil is suitable to continue through the two stage attrition scrubbing based on the cesium-137 concentration profile in the waste site; 49% of the total volume of contaminated soil is successfully treated and returned to the site. Fuel storage basin trenches and pluto cribs: 100% of the contaminated soil is suitable to continue through the two stage attrition scrubbing based on the cesium-137 concentration profile in the waste site; 61% of the total volume of contaminated material is successfully treated and returned to the site. Process effluent trenches, pipelines, and outfall structures: 0% of the contaminated soil is suitable to continue through the two stage attrition scrubbing based on the cesium-137 concentration profile in the waste site; 23% of the total volume of contaminated material is successfully treated and returned to the site. Future soil sites where 33% of the contaminated soil is suitable to continue through the two stage attrition scrubbing based on the cesium-137 concentration profile in the waste site; 36% of the total volume of contaminated material is successfully treated and returned to the site. SW-9: 90% of the contaminated material can be compacted by a factor of 50% of its original volume. The volume of waste contaminated with volatile and semi-volatile organic constituents only may be reduced completely.

Table 5-6 Detailed Analysis - Removal/Treatment/Disposal Alternative (SS-10/SW-9) (page 4 of 8)

REDUCTION OF TOXICITY, MOBILITY, OR VOLUME	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
To what extent are the effects of the treatment irreversible?	SS-10: Soil washing is irreversible. SW-9: Thermal desorption is irreversible. Compaction may be reversed with mechanical methods.
What are the quantities of residuals and characteristics of the residual risk?	SS-10: Soil washing may produce small amounts of residuals which are transferred to the disposal facility. SW-9: Thermal desorption will produce small amounts of residuals which are transferred to the disposal facility.
What risks do treatment of residuals pose?	None. No treatment proposed for residuals.
Is treatment used to reduce inherent hazards posed by principal threats at the site?	Treatment is used to reduce potential hazards at the disposal facility.

Table 5-6 Detailed Analysis - Removal/Treatment/Disposal Alternative (SS-10/SW-9) (page 5 of 8)

SHORT-TERM EFFECTIVENESS	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
What are the risks to the community during remedial actions, and how will they be mitigated?	Potential for releases of fugitive dusts during excavation and treatment. Appropriate engineering controls and contingency plans will be developed and implemented during the excavation and disposal.
What risks remain to the community that cannot be readily controlled?	None.
What are the risks to the workers, and how will they be mitigated?	Risks due to exposure or accident. Potential for releases of fugitive dusts during excavation and treatment. Risks can be controlled by implementing appropriate engineering controls and health and safety procedures. Short term risk is high.
What risks remain to the workers that cannot be readily controlled?	SS-10: Minimal uncertainty therefore all risks will be mitigated. SW-9: Unmitigated risks due to unknown buried wastes.
What environmental impacts are expected with the construction and implementation of the alternative?	Fugitive dust releases could possibly affect outlying environment but can be controlled through proper operating procedures. Remedial activities can be scheduled to accommodate nesting or roosting species. Short term risk is medium. Soil excavation may impact terrestrial species, where activities near the river may iumpact aquatic species.
What are the impacts that cannot be avoided should the alternative be implemented?	None.
How long until remedial response objectives are achieved?	All RAO are met upon completion of remedial alternative.

Table 5-6 Detailed Analysis - Removal/Treatment/Disposal Alternative (SS-10/SW-9) (page 6 of 8)

IMPLEMENTABILITY	retention basins, sludge trenches, fuel storage basin trenches, process effluent trenches, pluto cribs, dummy decontamination cribs/french drains, pipelines, burial grounds
What difficulties and uncertainties are associated with construction?	The extent of contamination is uncertain but will be delineated during excavation. SS-10: Two stage attrition scrubbing may be effective if the cesium-137 concentrations do not exceed twice the PRG. SW-9: Uncertainty exists concerning the nature of buried wastes and the problems with encountering unexpected materials.
What is the likelihood that technical problems will lead to schedule delays?	Delays not likely. No adaptations to excavation technology are expected. Some uncertainty on availability and schedule of the disposal facilities. SS-10: Soil washing performed off-line and have little potential to impact the schedule. SW-9: Compaction and thermal desorption are performed off-line and have little potential to impact the schedule.
What likely future remedial actions are anticipated?	None.
What risks of exposure exist should monitoring be insufficient to detect failure?	Removal does not require post closure monitoring.
What activities are proposed which require coordination with other agencies?	None.
Are adequate treatment, storage capacity, and disposal services available?	Yes. Maximum capacity at the W-025 facility is 25,000 yd^3, available in 1994. The ERDF capacity is 4.3 million yd^3, available in 1996. Remedial action will not be implemented until disposal is available.
Are necessary equipment and specialists available?	Yes. General earthwork construction equipment is required and is readily available. Excavation and analytical specialists are required and are available. Specialized analytical equipment may be required and is available. Excavation, analytical, and treatment equipment and specialists are required and are available.
Are technologies under consideration generally available and sufficiently demonstrated or will they require further development before they can be applied at the site?	Yes. Removal and disposal are developed technologies. SS-10: Excavation of the 116-F-4 pluto crib has been completed demonstrating many of the technologies to be used. Particle separation of cobbles and gravels from sands and fines is a demonstrated technology. Bench scale tests have shown attrition scrubbing to be fairly effective in treating sands contaminated when levels of cesium-137 do not exceed 2x the PRG. However, a field scale soil washing study is scheduled for late 1994 to verify the results of the bench scale study. SW-9: Excavation of the 118-B-1 burial ground will be conducted in the summer of 1994 to demonstrate the ability to excavate buried waste. Thermal desorption and compaction are developed technologies.
Will more than one vendor be available to provide a competitive bid?	Yes. Several general earthwork contractors exist locally. Many vendors are also available to supply monitoring, compaction, thermal desorption, and soil washing equipment.

Table 5-6 Detailed Analysis - Removal/Treatment/Disposal Alternative (SS-10/SW-9) (page 7 of 8)

COST	CAPITAL	O&M	PRESENT WORTH
retention basins	$102,000,000 •Includes Removal of the contaminated material and site restoration Transportation of the excavated material to a common disposal facility	$24,500,000 •Includes Treatment of the contaminated material (i.e., soil washing)	$114,000,000
sludge trenches	$2,130,000 •Includes Removal of the contaminated material and site restoration Transportation of the excavated material to a common disposal facility	$277,000 •Includes Treatment of the contaminated material (i.e., soil washing)	$2,300,000
fuel storage basin trenches	$4,880,000 •Includes Removal of the contaminated material and site restoration Transportation of the excavated material to a common disposal facility	$950,000 •Includes Treatment of the contaminated material (i.e., soil washing)	$5,570,000
process effluent trenches	$17,300,000 •Includes Removal of the contaminated material and site restoration Transportation of the excavated material to a common disposal facility	$1,450,000 •Includes Treatment of the contaminated material (i.e., soil washing)	$17,900,000
pluto cribs	$708,000 •Includes Removal of the contaminated material and site restoration Transportation of the excavated material to a common disposal facility	$9,240 •Includes Treatment of the contaminated material (i.e., soil washing)	$692,000
dummy decontamination cribs/french drains	$721,000 •Includes: Removal of the contaminated material and site restoration Transportation of the excavated material to a common disposal facility	$114,000 •Includes: Treatment of the contaminated material (i.e., soil washing)	$707,000

Table 5-6 Detailed Analysis - Removal/Treatment/Disposal Alternative (SS-10/SW-9) (page 8 of 8)

COST	CAPITAL	O&M	PRESENT WORTH
pipelines	$38,100,000 •Includes: Removal of the contaminated material and site restoration Transportation of the excavated material to a common disposal facility	$5,780,000 •Includes: Treatment of the contaminated material (i.e., soil washing)	$40,000,000
burial grounds	$2,510,000 •Includes: Removal of the contaminated material and site restoration Transportation of the excavated material to a common disposal facility	$137,000 •Includes: Treatment of the contaminated material (i.e., compaction and thermal desorption)	$2,530,000

ARAR - applicable, relevant and appropriate requirements
TBC - to-be-considered
O&M - operation and maintenance
RAO - remedial action objectives
PRG - preliminary remediation goals
ERDF - Environmental Restoration Disposal Facility

6.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

The comparative analysis of remedial alternatives evaluates the relative performance of each alternative with respect to seven of the nine specific EPA evaluation criteria presented in Section 5.0. The last two criteria: state (support agency) acceptance and community acceptance will be addressed following comment on this Process Document. The purpose of this comparative analysis is to identify the relative advantages and disadvantages of each alternative and thereby provide a sound basis for remedy selection.

The first two applicability criteria, overall protectiveness of human health and the environment and compliance with ARAR serve as threshold determinations in that they must be met by any alternative for it to be eligible for selection. The next five applicability criteria, long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness, implementability, and cost, are compared such that major "tradeoffs" among the alternatives are identified and weighed in the decision-making process.

The alternatives are compared for each waste site group (except D&D and seal pit cribs, because these groups have only one applicable alternative) and results are presented in Tables 6-1 to 6-9. Appendix B presents the cost estimate information for each waste site group.

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Table 6-1 Comparative Analysis - Retention Basins

COMPARATIVE EVALUATION CRITERIA	REMOVAL/DISPOSAL SS-4	REMOVAL/TREATMENT/DISPOSAL SS-10
Overall Protection of Human Health and the Environment	Nearly as effective as SS-10 since any potential risk is eliminated by removal of the source. Contaminated material, exceeding PRG, is excavated and transported to a common disposal facility (i.e., W-025 or ERDF).	More effective than SS-4 since any potential risk is eliminated by removal and treatment of the source. Contaminated material, exceeding PRG, is excavated, treated, and transported to a common disposal facility (i.e., W-025 or ERDF).
Compliance with ARAR	Both SS-4 and SS-10 comply with all chemical-, location-, and action-specific ARAR.	
Long-Term Effectiveness and Permanence	Both SS-4 and SS-10 are judged to offer the same degree of effectiveness in achieving RAO. Contaminated material, exceeding PRG, is removed and ultimately disposed thereby eliminating the potential source at the waste site.	
Reduction of Toxicity, Mobility, or Volume	Less effective than SS-10. All contaminated material, exceeding PRG, is removed and transported to a common disposal facility. No treatment is proposed, therefore, no reduction of mobility, toxicity, or volume is achieved. Radionuclides present in the contaminated material will naturally degrade.	More effective than SS-4. All contaminated material, exceeding PRG, is removed, treated, and transported to a common disposal facility. Treatment (i.e., soil washing) is proposed, therefore, the mass of contaminants present will be reduced (by an estimated 49%). Radionuclides present in the contaminated material will naturally degrade.
Short-Term Effectiveness	More effective than SS-10. Remedial action objectives are achieved within approximately 1.4 years. Potential sources of risk are removed through excavation and disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation.	Nearly as effective as SS-4. Remedial action objectives are achieved within approximately 3.2 years. Potential sources of risk are removed through excavation and the ultimate disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation and treatment.
Implementability	SS-4 offers a higher level of implementability compared to SS-10 since excavation is well demonstrated and no treatment is proposed.	SS-10 is readily implementable; however, a study is necessary to examine the effectiveness of soil washing at the field scale.
Present Worth*	$96,000,000	$114,000,000

* 5% discount rate

ARAR - applicable or relevant and appropriate requirement
O&M - operation and maintenance
PRG - preliminary remediation goal
ERDF - Environmental Restoration Disposal Facility
RAO - remedial action objectives

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Table 6-2 Comparative Analysis - Sludge Trenches

COMPARATIVE EVALUATION CRITERIA	REMOVAL/DISPOSAL SS-4	IN SITU TREATMENT SS-8A	REMOVAL/TREATMENT/DISPOSAL SS-10
Overall Protection of Human Health and the Environment	Nearly as effective as SS-10 but more effective than SS-8A. Potential risk is eliminated by removal of the source. Contaminated material, exceeding PRG, is excavated and transported to a common disposal facility (i.e., W-025 or ERDF).	Less effective than SS-4 and SS-10. Potential exposure risk pathways are reduced by immobilization of the contaminated material through encapsulation (i.e., vitrification). However, the encapsulated material remains at the waste site.	More effective than SS-4 and SS-8A since any potential risk is eliminated by removal and treatment of the source. Contaminated material, exceeding PRG, is excavated, treated, and transported to a common disposal facility (i.e., W-025 or ERDF).
Compliance with ARAR	SS-4, SS-8A, and SS-10 comply with all chemical-, location-, and action-specific ARAR.		
Long-Term Effectiveness and Permanence	More effective than SS-8A and equally effective as SS-10 in achieving RAO. Contaminated material, exceeding PRG, is removed and disposed thereby eliminating the potential source at the waste site.	Nearly as effective as SS-4 and SS-10. Remedial action objectives are achieved; however, contaminated material exceeding PRG is vitrified and remains at the waste site. Long-term O&M requirements consist of: maintenance of soil cover, deed restrictions, operation and maintenance of the vitrification system, and groundwater surveillance monitoring.	More effective than SS-8A and equally effective as SS-4 in achieving RAO. Contaminated material, exceeding PRG, is removed and ultimately disposed of thereby eliminating the potential source at the waste site.
Reduction of Toxicity, Mobility, or Volume	Less effective than SS-8A and SS-10. All contaminated material, exceeding PRG, is removed and transported to a common disposal facility. No treatment is proposed, therefore, no reduction of mobility, toxicity, or volume is achieved. Radionuclides present in the contaminated material will naturally degrade.	More effective than SS-4 and SS-10. Contaminants, exceeding PRG, are effectively immobilized and principle exposure pathways are eliminated through in situ treatment (i.e., vitrification). Hydraulic infiltration and contaminant mobilization are eliminated. Radionuclides present in the contaminated material will naturally degrade.	Nearly as effective as SS-8A but more effective than SS-4. All contaminated material, exceeding PRG, is removed, treated, and transported to a common disposal facility. Treatment (i.e., soil washing) is proposed, therefore, the mass of contaminants present will be reduced (by an estimated 49%). Radionuclides present in the contaminated material will naturally degrade.
Short-Term Effectiveness	Nearly as effective as SS-8A but more effective than SS-10. Remedial action objectives are achieved within approximately 0.1 years. Potential sources of risk are removed through excavation and disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation.	More effective than SS-4 and SS-10. Remedial action objectives are achieved within approximately 0.4 years. Potential sources of risk remain at the waste site; however, treatment immobilizes the contaminants and eliminates exposure pathways. Slight potential exists for worker exposure to contaminant offgas during treatment.	Less effective than SS-4 and SS-8A. Remedial action objectives are achieved within approximately 0.1 years. Potential sources of risk are removed through excavation and the ultimate disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation and treatment.
Implementability	SS-4 offers a higher level of implementability compared to SS-8A and SS-10 since excavation is well demonstrated and no treatment is proposed.	SS-8A is less implementable compared to SS-4 and SS-10 since it is an innovative technology. Site specific parameters such as location and subsurface geology must be adequately defined prior to implementation of the in situ treatment. In situ vitrification is has been proven to be effective to a maximum depth of 5.8 m (19 ft).	SS-10 offers a higher level of implementability compared to SS-8A but is less implementable than SS-4. Excavation is well demonstrated; however, a study is necessary to examine the effectiveness of soil washing at the field scale.
Present Worth*	$1,670,000	$5,630,000	$2,300,000

* 5% discount rate
ARAR - applicable or relevant and appropriate requirement
O&M - operation and maintenance
PRG - preliminary remediation goal
RAO - remedial action objective
ERDF - Environmental Restoration Disposal Facility

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Table 6-3 Comparative Analysis - Fuel Storage Basin Trenches

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COMPARATIVE EVALUATION CRITERIA	REMOVAL/DISPOSAL SS-4	REMOVAL/TREATMENT/DISPOSAL SS-10
Overall Protection of Human Health and the Environment	Nearly as effective as SS-10 since any potential risk is eliminated by removal of the source. Contaminated material, exceeding PRG, is excavated and transported to a common disposal facility (i.e., W-025 or ERDF).	More effective than SS-4 since any potential risk is eliminated by removal and treatment of the source. Contaminated material, exceeding PRG, is excavated, treated, and transported to a common disposal facility (i.e., W-025 or ERDF).
Compliance with ARAR	Both SS-4 and SS-10 comply with all chemical-, location-, and action-specific ARAR.	
Long-Term Effectiveness and Permanence	Both SS-4 and SS-10 are judged to offer the same degree of effectiveness in achieving RAO. Contaminated material, exceeding PRG, is removed and ultimately disposed thereby eliminating the potential source at the waste site.	
Reduction of Toxicity, Mobility, or Volume	Less effective than SS-10. All contaminated material, exceeding PRG, is removed and transported to a common disposal facility. No treatment is proposed, therefore, no reduction of mobility, toxicity, or volume is achieved. Radionuclides present in the contaminated material will naturally degrade.	More effective than SS-4. All contaminated material, exceeding PRG, is removed, treated, and transported to a common disposal facility. Treatment (i.e., soil washing) is proposed, therefore, the mass of contaminants present will be reduced (by approximately 36%). Radionuclides present in the contaminated material will naturally degrade.
Short-Term Effectiveness	More effective than SS-10. Remedial action objectives are achieved within approximately 0.2 years. Potential sources of risk are removed through excavation and disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation.	Nearly as effective as SS-4. Remedial action objectives are achieved within approximately 0.3 years. Potential sources of risk are removed through excavation and the ultimate disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation and treatment.
Implementability	SS-4 offers a higher level of implementability compared to SS-10 since excavation is well demonstrated and no treatment is proposed.	SS-10 is readily implementable; however, a study is necessary to examine the effectiveness of soil washing at the field scale.
Present Worth*	$4,470,000	$5,570,000

* 5% discount rate

ARAR - applicable or relevant and appropriate requirement
O&M - operation and maintenance
PRG - preliminary remediation goal
RAO - remedial action objectives
ERDF - Environmental Restoration Disposal Facility

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Table 6-4 Comparative Analysis - Process Effluent Trenches

COMPARATIVE EVALUATION CRITERIA	REMOVAL/DISPOSAL SS-4	IN SITU TREATMENT SS-8A	REMOVAL/TREATMENT/DISPOSAL SS-10
Overall Protection of Human Health and the Environment	Nearly as effective as SS-10 but more effective than SS-8A. Potential risk is eliminated by removal of the source. Contaminated material, exceeding PRG, is excavated and transported to a common disposal facility (i.e., W-025 or ERDF).	Less effective than SS-4 and SS-10. Potential exposure risk pathways are reduced by immobilization of the contaminated material through encapsulation (i.e., vitrification). Howevr, the encapsulated material remains at the waste site.	More effective than SS-4 and SS-8A since any potential risk is eliminated by removal and treatment of the source. Contaminated material, exceeding PRG, is excavated, treated, and transported to a common disposal facility (i.e., W-025 or ERDF).
Compliance with ARAR	SS-4, SS-8A, and SS-10 comply with all chemical-, location-, and action-specific ARAR.		
Long-Term Effectiveness and Permanence	More effective than SS-8A and equally effective as SS-10 in achieving RAO. Contaminated material, exceeding PRG, is removed and disposed thereby eliminating the potential source at the waste site.	Nearly as effective as SS-4 and SS-10. Remedial action objectives are achieved; however, contaminated material exceeding PRG is vitrified and remains at the waste site. Long-term O&M requirements consist of: maintenance of soil cover, deed restrictions, operation and maintenance of the vitrification system, and groundwater surveillance monitoring.	More effective than SS-8A and equally effective as SS-4 in achieving RAO. Contaminated material, exceeding PRG, is removed and ultimately disposed of thereby eliminating the potential source at the waste site.
Reduction of Toxicity, Mobility, or Volume	Less effective than SS-8A and SS-10. All contaminated material, exceeding PRG, is removed and transported to a common disposal facility. No treatment is proposed, therefore, no reduction of mobility, toxicity, or volume is achieved. Radionuclides present in the contaminated material will naturally degrade.	More effective than SS-4 and SS-10. Contaminants, exceeding PRG, are effectively immobilized and principle exposure pathways are eliminated through in situ treatment (i.e., vitrification). Hydraulic infiltration and contaminant mobilization are eliminated. Radionuclides present in the contaminated material will naturally degrade.	Nearly as effective as SS-8A but more effective than SS-4. All contaminated material, exceeding PRG, is removed, treated, and transported to a common disposal facility. Treatment (i.e., soil washing) is proposed, therefore, the mass of contaminants present will be reduced (by approximately 23%). Radionuclides present in the contaminated material will naturally degrade.
Short-Term Effectiveness	Nearly as effective as SS-8A but more effective than SS-10. Remedial action objectives are achieved within approximately 0.5 years. Potential sources of risk are removed through excavation and disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation.	More effective than SS-4 and SS-10. Remedial action objectives are achieved within approximately 3.8 years. Potential sources of risk remain at the waste site; however, treatment immobilizes the contaminants and eliminates exposure pathways. Slight potential exists for worker exposure to contaminant offgas during treatment.	Less effective than SS-4 and SS-8A. Remedial action objectives are achieved within approximately 0.6 years. Potential sources of risk are removed through excavation and the ultimate disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation and treatment.
Implementability	SS-4 offers a higher level of implementability compared to SS-8A and SS-10 since excavation is well demonstrated and no treatment is proposed.	SS-8A is less implementable compared to SS-4 and SS-10 since it is an innovative technology. Site specific parameters such as location and subsurface geology must be adequately defined prior to implementation of the in situ treatment. In situ vitrification has only been proven effective to a maximum depth of 5.8 m (19 ft).	SS-10 offers a higher level of implementability compared to SS-8A but is less implementable than SS-4. Excavation is well demonstrated; however, a study is necessary to examine the effectiveness of soil washing at the field scale.
Present Worth*	$15,700,000	$54,800,000	$17,900,000

* 5% discount rate ARAR - applicable or relevant and appropriate requirement RAO - remedial action objectives
O&M - operation and maintenance PRG - preliminary remediation goal ERDF - Environmental Restoration Disposal Facility

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Table 6-5 Comparative Analysis - Pluto Cribs

COMPARATIVE EVALUATION CRITERIA	REMOVAL/DISPOSAL SS-4	IN SITU TREATMENT SS-8A	REMOVAL/TREATMENT/DISPOSAL SS-10
Overall Protection of Human Health and the Environment	Nearly as effective as SS-10 but more effective than SS-8A. Potential risk is eliminated by removal of the source. Contaminated material, exceeding PRG, is excavated and transported to a common disposal facility (i.e., W-025 or ERDF).	Less effective than SS-4 and SS-10. Potential exposure risk pathways are reduced by immobilization of the contaminated material through encapsulation (i.e., vitrification). However, the encapsulated material remains at the waste site.	More effective than SS-4 and SS-8A since any potential risk is eliminated by removal and treatment of the source. Contaminated material, exceeding PRG, is excavated, treated, and transported to a common disposal facility (i.e., W-025 or ERDF).
Compliance with ARAR	SS-4, SS-8A, and SS-10 comply with all chemical-, location-, and action-specific ARAR.		
Long-Term Effectiveness and Permanence	More effective than SS-8A and equally effective as SS-10 in achieving RAO. Contaminated material, exceeding PRG, is removed and disposed thereby eliminating the potential source at the waste site.	Nearly as effective as SS-4 and SS-10. Remedial action objectives are achieved; however, contaminated material exceeding PRG is vitrified and remains at the waste site. Long-term O&M requirements consist of: maintenance of soil cover, deed restrictions, operation and maintenance of the vitrification system, and groundwater surveillance monitoring.	More effective than SS-8A and equally effective as SS-4 in achieving RAO. Contaminated material, exceeding PRG, is removed and ultimately disposed thereby eliminating the potential source at the waste site.
Reduction of Toxicity, Mobility, or Volume	Less effective than SS-8A and SS-10. All contaminated material, exceeding PRG, is removed and transported to a common disposal facility. No treatment is proposed, therefore, no reduction of mobility, toxicity, or volume is achieved. Radionuclides present in the contaminated material will naturally degrade.	More effective than SS-4 and SS-10. Contaminants, exceeding PRG, are effectively immobilized and principle exposure pathways are eliminated through in situ treatment (i.e., vitrification). Hydraulic infiltration and contaminant mobilization are eliminated. Radionuclides present in the contaminated material will naturally degrade.	Nearly as effective as SS-8A but more effective than SS-4. All contaminated material, exceeding PRG, is removed, treated, and transported to a common disposal facility. Treatment (i.e., soil washing) is proposed, therefore, the mass of contaminants present will be reduced (by approximately 61%). Radionuclides present in the contaminated material will naturally degrade.
Short-Term Effectiveness	Nearly as effective as SS-8A but more effective than SS-10. Remedial action objectives are achieved within approximately 0.1 years. Potential sources of risk are removed through excavation and disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation.	More effective than SS-4 and SS-10. Remedial action objectives are achieved within approximately 0.1 years. Potential sources of risk remain at the waste site; however, treatment immobilizes the contaminants and eliminates exposure pathways. Slight potential exists for worker exposure to contaminant offgas during treatment.	Less effective than SS-4 and SS-8A. Remedial action objectives are achieved within approximately 0.1 years. Potential sources of risk are removed through excavation and the ultimate disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation and treatment.
Implementability	SS-4 offers a higher level of implementability compared to SS-8A and SS-10 since excavation is well demonstrated and no treatment is proposed.	SS-8A is less implementable compared to SS-4 and SS-10 since it is an innovative technology. Site-specific parameters such as location and subsurface geology must be adequately defined prior to implementation of the in situ treatment. In situ vitrification has been proven effective to a maximum depth of 5.8 m (19 ft).	SS-10 offers a higher level of implementability compared to SS-8A but is less implementable than SS-4. Excavation is well demonstrated; however, a study is necessary to examine the effectiveness of soil washing at the field scale.
Present Worth*	$267,000	$661,000	$692,000

* 5% discount rate
ARAR - applicable or relevant and appropriate requirement
O&M - operation and maintenance
PRG - preliminary remediation goal
RAO - remedial action objectives
ERDF - Environmental Restoration Disposal Facility

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Table 6-6 Comparative Analysis - Dummy Decontamination Cribs and French Drains

COMPARATIVE EVALUATION CRITERIA	CONTAINMENT SS-3	REMOVAL/DISPOSAL SS-4	IN SITU TREATMENT SS-8A	REMOVAL/TREATMENT/DISPOSAL SS-10
Overall Protection of Human Health and the Environment	Less effective than SS-4, SS-8A, and SS-10. Potential exposure risk pathways are reduced/eliminated by installation of a engineered barrier over the contaminated material. However, the contaminated material remains at the waste site.	Nearly as effective as SS-10 but more effective than SS-3 and SS-8A. Potential risk is eliminated by removal of the source. Contaminated material, exceeding PRG, is excavated and transported to a common disposal facility (i.e., W-025 or ERDF).	More effective than SS-3 but less effective than SS-4 and SS-10. Potential exposure risk pathways are reduced by immobilization of the contaminated material through encapsulation (i.e., vitrification). However, the encapsulated material remains at the waste site.	More effective than SS-3, SS-4 and SS-8A since any potential risk is eliminated by removal and treatment of the source. Contaminated material, exceeding PRG, is excavated, treated, and transported to a common disposal facility (i.e., W-025 or ERDF).
Compliance with ARAR	SS-3, SS-4, SS-8A, and SS-10 comply with all chemical-, location-, and action-specific ARAR.			
Long-Term Effectiveness and Permanence	Less effective than SS-4, SS-8A, and SS-10. Remedial action objectives are achieved; however,contaminated material exceeding PRG remains at the waste site. Long-term O&M requirements consist of: repair and maintenance of engineered barrier, deed restrictions, and groundwater surveillance monitoring.	More effective than SS-3 and SS-8A and equally effective as SS-10 in achieving RAO. Contaminated material, exceeding PRG, is removed and disposed thereby eliminating the potential source at the waste site.	Nearly as effective as SS-4 and SS-10 but more effective than SS-3. Remedial action objectives are achieved; however, contaminated material exceeding PRG is vitrified and remains at the waste site. Long-term O&M requirements consist of: maintenance of soil cover, deed restrictions, operation and maintenance of the vitrification system, and groundwater surveillance monitoring.	More effective than SS-3 and SS-8A and equally effective as SS-4 in achieving RAO. Contaminated material, exceeding PRG, is removed and ultimately disposed thereby eliminating the potential source at the waste site.
Reduction of Toxicity, Mobility, or Volume	Less effective than SS-4, SS-8A and SS-10. All contaminated material, exceeding PRG, remains at the waste site. No treatment is proposed, therefore, no reduction of toxicity, mobility, or volume is achieved. Contaminants are effectively immobilized by the engineered barrier through reduction in hydraulic infiltration. Radionuclides present in the contaminated material will naturally degrade.	Less effective than SS-8A and SS-10 but more effective than SS-3. All contaminated material, exceeding PRG, is removed and transported to a common disposal facility. No treatment is proposed, therefore, no reduction of mobility, toxicity, or volume is achieved. Radionuclides present in the contaminated material will naturally degrade.	More effective than SS-3, SS-4, and SS-10. Contaminants, exceeding PRG, are effectively immobilized and principle exposure pathways are eliminated through in situ treatment (i.e., vitrification). Hydraulic infiltration and contaminant mobilization are eliminated. Radionuclides present in the contaminated material will naturally degrade.	Nearly as effective as SS-8A but more effective than SS-3 and SS-4. All contaminated material. exceeding PRG, is removed, treated, and transported to a common disposal facility. Treatment (i.e., soil washing) is proposed, therefore, the mass of contaminants present will be reduced (by approximately 49%). Radionuclides present in the contaminated material will naturally degrade.
Short-Term Effectiveness	More effective than SS-4, SS-8A. and SS-10. Remedial action objectives are achieved within approximately 0.1 years. Potential sources of risk remain at the waste site; however, installation of an engineered barrier effectively immobilizes the contaminants and eliminates exposure pathways. The contaminated soil is not disturbed during the remedial action.	Nearly as effective as SS-8A, more effective than SS-10, and less effective than SS-3. Remedial action objectives are achieved within approximately 0.1 years. Potential sources of risk are removed through excavation and disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation.	More effective than SS-4 and SS-10 but not as effective as SS-3. Remedial action objectives are achieved within approximately 0.1 years. Potential sources of risk remain at the waste site; however, treatment immobilizes the contaminants and eliminates exposure pathways. Slight potential exists for worker exposure to contaminant offgas during treatment.	Less effective than SS-3, SS-4 and SS-8A. Remedial action objectives are achieved within approximately 0.1 years. Potential sources of risk are removed through excavation and the ultimate disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation and treatment.
Implementability	SS-3 is more implementable than SS-4, SS-8A and SS-10 since no intrusive activities are proposed. Installation of an engineered barrier is well demonstrated.	SS-4 offers a higher level of implementability compared to SS-8A and SS-10 but is less implementable compared to SS-3. Excavation is well demonstrated and no treatment is proposed.	SS-8A is less implementable compared to SS-3, SS-4, and SS-10 since it is an innovative887Xtechnology. Site-specific parameters such as location and subsurface geology must be adequately defined prior to implementation of the in situ treatment. In situ vitrification has only been proven effective to a maximum depth of 5.8 m (19 ft).	SS-10 is more implementable than SS-8A but less implementable compared to SS-3 and SS-4. Excavation is well demonstrated; however, a study is necessary to examine the effectiveness of soil washing at the field scale.
Present Worth*	$454,000	$283,000	$715,000	$707,000

* 5% discount rate ARAR - applicable or relevant and appropriate requirement O&M - operation and maintenance
PRG - preliminary remediation goal RAO - remedial action alternatives ERDF - Environmental Restoration Disposal Facility

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Table 6-7 Comparative Analysis - Pipelines
(page 1 of 2)

COMPARATIVE EVALUATION CRITERIA	CONTAINMENT SS-3	REMOVAL/DISPOSAL SS-4	IN SITU TREATMENT SS-8B	REMOVAL/TREATMENT/DISPOSAL SS-10
Overall Protection of Human Health and the Environment	Less effective than SS-4, SS-8B, and SS-10. Potential exposure risk pathways are reduced/eliminated by installation of a engineered barrier over the pipeline and associated contaminated material. However, the pipeline and contaminated material remains at the waste site.	Nearly as effective as SS-10 but more effective than SS-3 and SS-8B. Potential risk is eliminated by removal of the pipeline and associated contaminated material. Contaminated material, exceeding PRG, and the pipeline is excavated and transported to a common disposal facility (i.e., W-025 or ERDF).	More effective than SS-3 but less effective than SS-4 and SS-10. Potential exposure risk pathways are reduced by immobilization of the contaminated material through encapsulation (i.e., grouting the pipeline), and installation of an engineered barrier over the pipeline and associated contaminated material. However, the pipeline and contaminated material remain at the waste site.	More effective than SS-3, SS-4 and SS-8B since any potential risk is eliminated by removal of the pipeline and removal and treatment of the contaminated material. Contaminated material, exceeding PRG, is excavated, treated, and transported to a common disposal facility along with the excavated pipeline (i.e., W-025 or ERDF).
Compliance with ARAR	SS-3, SS-4, SS-8B, and SS-10 comply with all chemical-, location-, and action-specific ARAR.			
Long-Term Effectiveness and Permanence	Less effective than SS-4, SS-8B, and SS-10. Remedial action objectives are achieved; however, contaminated material exceeding PRG, and the pipeline remain at the waste site. Long-term O&M requirements consist of: repair and maintenance of the engineered barrier, deed restrictions, and groundwater surveillance monitoring.	More effective than SS-3 and SS-8B and equally effective as SS-10 in achieving RAO. The pipeline and associated contaminated material, exceeding PRG, is removed and disposed thereby eliminating the potential source at the waste site.	Nearly as effective as SS-4 and SS-10 but more effective than SS-3. Remedial action objectives are achieved. Contaminated material (i.e., sludge) will be stabilized through grouting the pipeline. Additionally, an engineered barrier will be installed over the pipeline and the associated contaminated material. The contaminated materials however remain at the waste site. Long-term O&M requirements consist of: maintenance of the engineered barrier, deed restrictions, and groundwater surveillance monitoring.	More effective than SS-3 and SS-8B and equally effective as SS-4 in achieving RAO. Contaminated material, exceeding PRG, is removed and ultimately disposed thereby eliminating the potential source at the waste site.
Reduction of Toxicity, Mobility, or Volume	Less effective than SS-4, SS-8B and SS-10. All contaminated material, exceeding PRG, remains at the waste site. No treatment is proposed, therefore, no reduction of toxicity, mobility, or volume is achieved. Contaminants are effectively immobilized by the engineered barrier through reduction in hydraulic infiltration. Radionuclides present in the contaminated material will naturally degrade.	Less effective than SS-8B and SS-10 but more effective than SS-3. All contaminated material, exceeding PRG, is removed and transported to a common disposal facility. No treatment is proposed, therefore, no reduction of mobility, toxicity, or volume is achieved. Radionuclides present in the contaminated material will naturally degrade.	More effective than SS-3, SS-4, and SS-10. Contaminants, exceeding PRG, are effectively immobilized and principle exposure pathways are eliminated through in situ treatment (i.e., grouting). Principle exposure pathways are also eliminated through installation of an engineered barrier. Hydraulic infiltration and contaminant mobilization are eliminated. Radionuclides present in the contaminated material will naturally degrade.	Nearly as effective as SS-8B but more effective than SS-3 and SS-4. All contaminated material, exceeding PRG, is removed, treated, and transported to a common disposal facility. Treatment (i.e., soil washing) is proposed, therefore, the mass of contaminants present will be reduced (by approximately 23%). Radionuclides present in the contaminated material will naturally degrade.
Short-Term Effectiveness	More effective than SS-4, SS-8B, and SS-10. Remedial action objectives are achieved within approximately 2.4 years. Potential sources of risk remain at the waste site; however, installation of an engineered barrier effectively immobilizes the contaminants and eliminates exposure pathways. The contaminated soil is not disturbed during the remedial action.	Nearly as effective as SS-8B, more effective than SS-10, and less effective than SS-3. Remedial action objectives are achieved within approximately 2.4 years. Potential sources of risk are removed through excavation and disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation.	More effective than SS-4 and SS-10 but not as effective as SS-3. Remedial action objectives are achieved within approximately 0.2 years. Potential sources of risk remain at the waste site; however, grouting of the pipeline immobilizes the contaminants and installation of an engineered barrier eliminates exposure pathways. The contaminated soil is not disturbed during the remedial action.	Less effective than SS-3, SS-4 and SS-8B. Remedial action objectives are achieved within approximately 2.5 years. Potential sources of risk are removed through excavation and the ultimate disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation and treatment.

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Table 6-7 Comparative Analysis - Pipelines
(page 2 of 2)

COMPARATIVE EVALUATION CRITERIA	CONTAINMENT SS-3	REMOVAL/DISPOSAL SS-4	IN SITU TREATMENT SS-8B	REMOVAL/TREATMENT/DISPOSAL SS-10
Implementability	SS-3 is more implementable than SS-4, SS-8B and SS-10 since no intrusive activities are proposed. Installation of an engineered barrier is well demonstrated.	SS-4 offers a higher level of implementability compared to SS-10 but is less implementable compared to SS-3, and is equally implementable compared to SS-8B. Excavation is well demonstrated and no treatment is proposed.	SS-8B offers a higher level of implementability compared to SS-10, is less implementable compared to SS-3, and is equally implementable compared to SS-4. Grouting of pipelines is a well demonstrated and available technology.	SS-10 is more implementable than SS-8B but less implementable compared to SS-3 and SS-4. Excavation is well demonstrated; however, a study is necessary to examine the effectiveness of soil washing at the field scale.
Present Worth*	$54,600,000	$32,900,000	$8,870,000	$40,000,000

* 5% discount rate
O&M - operation and maintenance
RAO - remedial action objectives
ARAR - applicable or relevant and appropriate requirement
PRG - preliminary remediation goal
ERDF - Environmental Restoration Disposal Facility

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**Table 6-8 Comparative Analysis - Burial Grounds
(page 1 of 2)**

COMPARATIVE EVALUATION CRITERIA	CONTAINMENT SW-3	REMOVAL/DISPOSAL SW-4	IN SITU TREATMENT SW-7	REMOVAL/TREATMENT/DISPOSAL SW-9
Overall Protection of Human Health and the Environment	Less effective than SW-4, SW-7, and SW-9. Potential exposure risk pathways are reduced/eliminated by installation of a engineered barrier over the contaminated material. However, the contaminated material remains at the waste site.	Nearly as effective as SW-9 but more effective than SW-3 and SW-7. Potential risk is eliminated by removal of the contaminated material. Contaminated material, exceeding PRG, is excavated and transported to a common disposal facility (i.e., W-025 or ERDF).	More effective than SW-3 but less effective than SW-4 and SW-9. Potential exposure risk pathways are reduced by installation of an engineered barrier over the contaminated material. Dynamic compaction of the contaminated materials reduce the mobility of contaminants. However, the contaminated materials remain at the waste site.	More effective than SW-3, SW-4 and SW-7 since any potential risk is eliminated by removal and treatment of the contaminated material. Contaminated material, exceeding PRG, is excavated, treated, and transported to a common disposal facility along with the excavated pipeline (i.e., W-025 or ERDF).
Compliance with ARAR	SW-3, SW-4, SW-7, and SW-9 comply with all chemical-, location-, and action-specific ARAR.			
Long-Term Effectiveness and Permanence	Less effective than SW-4, SW-7, and SW-9. Remedial action objectives are achieved; however, contaminated material exceeding PRG, remain at the waste site. Long-term O&M requirements consist of: repair and maintenance of the engineered barrier, deed restrictions, and groundwater surveillance monitoring.	More effective than SW-3 and SW-7 and equally effective as SW-9 in achieving RAO. The contaminated material, exceeding PRG, is removed and disposed thereby eliminating the potential source at the waste site.	Nearly as effective as SW-4 and SW-9 but more effective than SW-3. Remedial action objectives are achieved. Contaminated material will be compacted prior to installation of an engineered barrier over the contaminated material. The contaminated materials however remain at the waste site. Long-term O&M requirements consist of: maintenance of the engineered barrier, deed restrictions, and groundwater surveillance monitoring.	More effective than SW-3 and SW-9 and equally effective as SW-4 in achieving RAO. Contaminated material, exceeding PRG, is removed and ultimately disposed thereby eliminating the potential source at the waste site. Long-term O&M requirements consist of: operation and maintenance of the thermal desorption system.
Reduction of Toxicity, Mobility, or Volume	Less effective than SW-4, SW-7 and SW-9. All contaminated material, exceeding PRG, remains at the waste site. No treatment is proposed, therefore, no reduction of toxicity, mobility, or volume is achieved. Contaminants are effectively immobilized by the engineered barrier through reduction in hydraulic infiltration. Radionuclides present in the contaminated material will naturally degrade.	Less effective than SW-7 and SW-9 but more effective than SW-3. All contaminated material, exceeding PRG, is removed and transported to a common disposal facility. No treatment is proposed, therefore, no reduction of mobility, toxicity, or volume is achieved. Radionuclides present in the contaminated material will naturally degrade.	More effective than SW-3, SW-4, and SW-9. Contaminants, exceeding PRG, are dynamically compacted and principle exposure pathways are eliminated through installation of an engineered barrier. Hydraulic infiltration and contaminant mobilization are minimized. Radionuclides present in the contaminated material will naturally degrade.	Nearly as effective as SW-7 but more effective than SW-3 and SW-4. All contaminated material, exceeding PRG, is removed, treated, and transported to a common disposal facility. Treatment (i.e., compaction and thermal desorption) is proposed, therefore, the mass of contaminants present will be reduced (by approximately 50%). Radionuclides present in the contaminated material will naturally degrade.
Short-Term Effectiveness	More effective than SW-4, SW-7, and SW-9. Remedial action objectives are achieved within approximately 0.1 years. Potential sources of risk remain at the waste site; however, installation of an engineered barrier effectively immobilizes the contaminants and eliminates exposure pathways. The contaminated material is not disturbed during the remedial action.	Nearly as effective as SW-7, more effective than SW-9, and less effective than SW-3. Remedial action objectives are achieved within approximately 0.1 years. Potential sources of risk are removed through excavation and disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation.	More effective than SW-4 and SW-9 but not as effective as SW-3. Remedial action objectives are achieved within approximately 0.1 years. Potential sources of risk remain at the waste site; however, installation of an engineered barrier eliminates exposure pathways. The contaminated material is not disturbed during the remedial action.	Less effective than SW-3, SW-4 and SW-7. Remedial action objectives are achieved within approximately 0.1 years. Potential sources of risk are removed through excavation and the ultimate disposal of contaminated materials exceeding PRG. Potential exists for worker exposure to contaminants during excavation and treatment.

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Table 6-8 Comparative Analysis - Burial Grounds (page 2 of 2)

COMPARATIVE EVALUATION CRITERIA	CONTAINMENT SW-3	REMOVAL/DISPOSAL SW-4	IN SITU TREATMENT SW-7	REMOVAL/TREATMENT/DISPOSAL SW-9
Implementability	SW-3 is more implementable than SW-4, SW-7 and SW-9 since no intrusive activities are proposed.	SW-4 offers a higher level of implementability compared to SW-7 and SW-9 but is less implementable compared to SW-3. Excavation is well demonstrated and no treatment is proposed.	SW-7 is less implementable compared to SW-3, SW-4, and SW-9 since the extent of contamination needs to be adequately defined prior to implementation of the remedial action. Location of existing buildings and waste sites needs to be considered.	SW-9 is more implementable than SW-7 but less implementable compared to SW-3 and SW-4. Excavation is well demonstrated; however, a study is necessary to examine the effectiveness of treatment at the field scale.
Present Worth*	$1,450,000	$2,380,000	$1,690,000	$2,530,000

* 5% discount rate
O&M - operation and maintenance
RAO - remedial action objectives
ARAR - applicable or relevant and appropriate requirement
PRG - preliminary remediation goal
ERDF - Environmental Restoration Disposal Facility

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Comparative Analysis Summary[1]

Evaluation Criteria / Waste Site Groups (Table Reference)	Retention Basins (Table 6-1)		Sludge Trenches (Table 6-2)			Fuel Storage Basin Trenches (Table 6-3)		Process Effluent Trenches (Table 6-4)			Pluto Cribs (Table 6-5)			Dummy Decontamination Cribs and French Drains (Table 6-6)				Pipelines (Table 6-7)				Burial Grounds (Table 6-8)			
Alternatives[2]	SS-4	SS-10	SS-4	SS-8A	SS-10	SS-4	SS-10	SS-4	SS-8A	SS-10	SS-4	SS-8A	SS-10	SS-3	SS-4	SS-8A	SS-10	SS-3	SS-4	SS-8B	SS-10	SW-3	SW-4	SW-7	SW-9
Overall Protection of Human Health and Environment	Better	Best	Better	Good	Best	Better	Best	Better	Good	Best	Better	Good	Best	Fair	Better	Good	Best	Poor	Better	Fair	Best	Fair	Better	Good	Best
Compliance with ARAR[3]	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best	Best
Long-Term Effectiveness and Permanence	Better	Better	Better	Good	Better	Better	Better	Better	Good	Better	Better	Good	Better	Fair	Better	Good	Better	Fair	Best	Better	Best	Fair	Best	Better	Best
Reduction of Toxicity, Mobility, and Volume	Poor	Better	Poor	Best	Better	Poor	Better	Poor	Best	Better	Poor	Best	Better	Poor	Fair	Best	Better	Fair	Good	Best	Better	Fair	Good	Best	Better
Short-Term Effectiveness	Best	Better	Better	Best	Good	Best	Better	Better	Best	Good	Better	Best	Good	Best	Good	Better	Fair	Best	Good	Better	Fair	Best	Good	Better	Fair
Implementability	Best	Good	Best	Fair	Good	Best	Good	Best	Fair	Good	Best	Fair	Good	Best	Better	Fair	Good	Best	Good	Good	Fair	Best	Better	Fair	Good
Present Worth[4] (millions $)	96	114	1.7	5.6	2.3	4.5	5.6	15.7	54.8	17.9	0.27	0.66	0.69	0.45	0.28	0.72	0.71	55	33	8.9	40	1.5	2.4	1.7	2.5

Notes:

1. Comparative Analysis Summary is based on Tables 6-1 through 6-8. Comparisons are made between relevant alternatives for each individual waste site group only.
2. Alternatives are summarized from Table 5-1.
   - SS-3/SW-3 Containment
   - SS-4/SW-4 Removal & Disposal
   - SW-7 In Situ Treatment of Solid Waste
   - SS-8A In Situ Treatment of Soils (except pipelines)
   - SS-8B In Situ Treatment of Soils (pipelines)
   - SW-9 Removal, Treatment, & Disposal of Solid Waste
   - SS-10 Removal, Treatment, & Disposal of Soil
3. ARAR - applicable or relevant and appropriate requirement
4. Cost is present worth at 5% discount rate.

Key:
- Best
- Better
- Good
- Fair
- Poor

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APPENDIX A

DEVELOPMENT OF PRELIMINARY REMEDIATION GOALS

1.0 PURPOSE AND OBJECTIVE

This appendix presents the development of PRG for the 100 Area source operable unit FFS. Preliminary remediation goals are numeric expressions of the RAO, and establish initial concentrations that are considered protective of human health and the environment for the defined land use (DOE-RL 1994a). These initial concentrations are used to estimate the extent of contamination which in turn defines the volume of waste to be addressed by remedial alternatives. The PRG are also used to assess the performance of remedial alternatives by defining a numeric goal to be achieved by treatment technologies. The objective of this methodology is to develop an appropriate and substantiated set of PRG for COPC that can be used to support the FFS.

For the remedial action to be successful, the PRG must (EPA 1988):

- protect human health and the environment
- attain ARAR.

Protectiveness of human health and the environment is established through risk assessment which requires definition of receptors and exposure pathways. Applicable, relevant and appropriate requirements have already been identified for the FFS and are presented in Section 2.0 of the Process Document (Tables 2-2 through 2-10).

The following sections present the identification of receptors and exposure pathways, and the development of PRG. Section 2.0 of this appendix presents an exposure model for human and ecological risk assessment. Initially, a conceptual pathway model was developed, which covered all possible receptors and exposure pathways. The model was then refined to include only those receptors and pathways applicable to the feasibility study process. Finally, risk equations for the significant receptors and pathways are presented in Section 3.0 of this appendix.

2.0 RECEPTORS AND EXPOSURE PATHWAYS

This section presents the conceptual pathway model, receptors, exposure pathways, and points of compliance based on a recreational land-use scenario and general conditions of the 100 Area.

2.1 CONCEPTUAL PATHWAY MODEL

The conceptual pathway model for the source operable units is presented in Figure A-1 and is based on a recreational land-use scenario (see Section 2.3 of the report) and the general conditions of the 100 Area source operable units. The primary receptors are:

- human site visitors and site workers
- terrestrial biota.

The primary exposure routes to humans are inhalation, ingestion and external radiation exposure to contaminants in soil. Terrestrial biota are assumed in this FFS to be exposed to contaminants in soil via ingestion of contaminated seeds by the mouse, and by direct uptake of soil contaminants by plants.

2.2 RECEPTORS

Human receptors at any given site are assumed to be a visitor or an onsite worker. As shown in Figure A-1, the visitor is considered a long-term receptor (i.e., site user under a recreational land-use), whereas the site worker is considered a short-term receptor (exposed during remediation). In both cases, the major exposure routes are the same: inhalation, ingestion, and exposure to external radiation; therefore, these routes were used to develop the PRG.

The terrestrial biota identified in Figure A-1 can potentially include all biota that may enter the site. However, two biota, one animal and one plant, are selected as representative of terrestrial biota in the 100 Areas. These biota are the Great Basin pocket mouse and a generic plant.

2.3 EXPOSURE POINTS/POINTS OF COMPLIANCE

Human and ecological receptors come in contact with contaminants at specific locations within an operable unit. If the principal source of the contaminants is soil, as it is for the source operable units (see Figure A-1), then the depth of the contaminants in the soil must be considered. For example, if the contaminants exist only at depths >1 m and the ground is not disturbed extensively (as in the recreational scenario), then humans will not come in contact with these buried contaminants (It is assumed that 1 m of clean soil adequately reduces radiation from radionuclides to acceptable levels.). Therefore, contaminants at depths >1 m are not considered for evaluating risks to humans or for establishing PRG relative to protecting humans.

In order to establish PRG for the source operable units, four exposure zones (exposure points or points of compliance) were developed to reflect how the receptors come in contact with contaminants in soil. The exposure zones are based on the major exposure pathways shown in Figure A-1; the minor exposure pathways were not considered. The exposure zones are shown in Table A-1 and are defined as follows:

- Zone 1 - Humans are exposed to soil contaminants near the ground surface by inhaling vapors or soil particulates, by ingesting soil, and by radiation from radionuclide contaminants. Humans are not exposed to contaminants at depths below the zone where recreational activities may disturb the soils, except for radiation from radionuclides down to a depth of 1 m. Exposure Zone 1 (surface to 1 m) is the only zone where human exposure is considered when developing PRG (Table A-1).

- Zone 2 - Animals in the area, such as the pocket mouse, may burrow into the soil for some distance, therefore, the exposure zone for animals is assumed to be from the surface to 2 m deep (WHC 1994a). Animals may be exposed to contaminant by ingestion of contaminated plants (including roots) or soil, by inhalation of soil particulates or vapor, and radiation from radionuclides. For developing PRG, only the ingestion of plant material was evaluated. Exposure Zones 1 and 2 are the animal exposure zones.

- Zone 3 - Plant roots can penetrate into soils for 2 or 3 m, therefore, can take up contaminants in soils from the surface down to 3 m. For developing PRG, only the direct uptake of contaminants from soils within the root zone were evaluated. Exposure zones 1, 2, and 3 are the depths where plants are exposed to site contaminants (Table A-1).

- Zone 4 - Living organisms at the source operable units are not exposed to contaminants that occur at depths >3 m. However, leachable contaminants located at any depth in the vadose zone may migrate into groundwater. Therefore, contaminants at depths below 3 m (and 0 to 3 m) must be considered relative to groundwater protection. Zone 4 was established to account for the potential influence of leachable contaminants that occur at depths below the three shallower zones where living organisms might be exposed. Only groundwater protection is considered within Zone 4 (depth >3 m). Table A-1 summarizes the specific pathways and receptors used to develop PRG for this FFS.

2.4 SPECIFIC PATHWAYS AND RECEPTORS USED FOR PRG DEVELOPMENT

Exposure pathways used in the development of human health PRG are consistent with that used in the QRA evaluation. The PRG protective of human health were adopted in place of species-specific ecological PRG in the zones accessible by ecological receptors. Potential impacts to individual organisms were used in the development of PRG, rather than attempting to assess the potential impact on ecological populations, communities, or ecosystems. Basing PRG on individuals rather than on populations or communities where significant ecological impacts would occur may be conservative, but a conservative approach was selected to offset the uncertainty in using PRG protective of humans rather than representative plants or animals. The PRG development incorporates a quantitative assessment of potential impact to groundwater by calculating soil concentrations which are protective of the groundwater resource.

3.0 PRELIMINARY REMEDIATION GOALS

The RAO are specific applicability criteria that the remediation will fulfill. The COPC developed in Section 2.1 are used to define the RAO. These objectives can be numerically expressed as PRG. The PRG establish initial concentrations that are considered protective of human health and the environment for the defined land use. The RAO are defined below:

- <u>For Human Health</u>
    - Limit exposure of human receptors to contaminated surface and subsurface soils in order to maintain receptor risk in the range of 10^{-04} to 10^{-06} for carcinogenic constituents, and at or below the PRG for noncarcinogenic constituents. This will be accomplished by eliminating exposure pathways or reducing contaminant concentrations.
    - Limit future impacts to groundwater by ensuring that contamination which may remain in the vadose zone will be at or below levels considered protective of groundwater.
    - Strive to comply with ARAR to the extent practicable.

- <u>For Environmental Protection:</u>
    - Limit exposure of ecological receptors to contaminants by minimizing contaminant concentration or accessibility.
    - Strive to comply with ARAR to the extent practicable.

Final remediation goals will be determined by the signatories to the Tri-Party Agreement when the remedy is selected and will be documented in the ROD.

A number of factors must be considered while developing PRG to satisfy the RAO listed above. In addition to considering contaminant concentrations that are protective of human health, ecological resources, and groundwater, several other factors must be considered. These factors include the background concentrations of natural soil constituents that might also be site contaminants (e.g., chromium and uranium), the limits of detection that analytical laboratories can achieve, and the federal and state regulatory limits for levels of contamination in soil, air, and water. The main factors used for developing PRG are discussed below and the specific concentrations used as PRG for each COPC are identified in Table A-2. As shown in Table A-2 the final PRG may be based on any of the factors discussed above.

3.1 HUMAN HEALTH

Risks to human health stem from carcinogenic and noncarcinogenic effects. Radionuclides and some nonradionuclides can induce carcinogenic effects on humans, and many radionuclides pose noncarcinogenic risk as well. The following subsections define the carcinogenic and noncarcinogenic PRG for humans.

3.1.1 Carcinogenic Constituents

Preliminary remediation goals calculated from a target risk are developed to define soil concentrations which are protective of human health exposures to carcinogenic compounds. Table A-2 identifies PRG for constituents with carcinogenic effects. These values are determined by back-calculating a concentration (PRG) from a target risk for the recreational land use scenario. The primary RAO for human health is to reduce risk from contamination to a level between 1×10^{-4} and 1×10^{-6}. A target risk of 1×10^{-6} has been defined for human health risks from individual carcinogenic constituents. The 1×10^{-6} calculation accounts for radioactive decay to the year 2018 (earliest possible date for recreational land-use).

Following the *Hanford Site Baseline Risk Assessment Methodology* (HSBRAM) (DOE-RL 1993a), the equation for calculating recreational human risk due to carcinogenic components is:

Target Risk = (Ingestion Risk + Inhalation Risk + External Risk)
= $\Sigma(\text{Intake} \times \text{SF})_i$ (where i = ingestion, inhalation, and external radiation)
= $\Sigma(\text{IF} \times \text{SC} \times \text{SF})_i$

Where
IF = Intake Factor
SC = Soil Concentration
SF = Carcinogenic Slope Factor (EPA 1992)

Because SC is the same for all three exposure routes it can be brought out of the summation:

$$\text{Target Risk} = \text{SC} \times \Sigma(\text{IF} \times \text{SF})_i$$

This can be rearranged to:

$$\text{SC} = \frac{\text{Target Risk}}{\Sigma(\text{IF} \times \text{SF})_i} = \text{PRG}_{\text{non-rad}} \qquad (1)$$

Equation one is used to determine the soil concentration of nonradionuclide carcinogenic contaminants. This relationship is shown in the equation:

$$SC_t = SC_0 \times DF$$

where: SC_t = soil concentration at time=t (nominally 2018)
SC_0 = soil concentration at time zero (assumed to be 1994).
DF = decay factor = 0.5^{β}
β = (future time - 1994)/$T_{0.5}$)
$T_{0.5}$ is the radionuclide specific half-life (y)

Using these relationships equation one can be rearranged to account for radionuclide decay:

$$SC_0 = \frac{\text{Target Risk}}{0.5^{\beta} \times \Sigma(\text{IF} \times \text{SF})_i} = PRG_{rad} \qquad (2)$$

Equation two calculates the allowable radionuclide soil concentrations in 1994 to meet the target risk in 2018.

The intake factors listed in these equations are specific to each exposure route and scenario. However, the recreational-scenario is the only scenario considered; thus three sets of intake factor equations must be defined (one each for inhalation, ingestion, and external). The equations for these factors are presented below:

Inhalation Intake Factors

$$\textit{Radionuclide Inhalation Intake} = \frac{(C\ pCi/g)(20\ m^3/d)(7\ d/y)(30\ y)}{(2x10^7\ m^3/kg)(0.001\ kg/g)} \qquad (3)$$

Or, Radionuclide Inhalation Intake = (0.21 g) x C(pCi/g).

$$\textit{Chemical Inhalation Dose Rate} = \frac{(C\ mg/kg)(20\ m^3/d)(7\ d/y)(30\ y)}{(70\ kg)(25{,}550\ d)(2x10^7\ m^3/kg)} \qquad (4)$$

Or, Chemical Inhalation Dose Rate = $1.17 \times 10^{-10}(d^{-1})$ x C (mg/kg).

Ingestion Intake Factors

Or, Radionuclide Intake Factor = I

$$I = (C\ pCi/g)(10^{-3}\ g/mg)\ [(200\ mg/d)(7\ d/y)(6\ y) + (100\ mg/d)(7\ d/y)(24\ y)] \qquad (5)$$

Or, Radionuclide Ingestion Intake = 25.2 (g) x C (pCi/g).

Chemical ingestion intake = IDR

$$IDR = (C\ mg/kg)(10^{-6}\ kg/mg)x\frac{\frac{(200\ mg/d)(7\ d/y)(6\ y)}{(16\ kg)}+\frac{(100\ mg/d)(7\ d/y)(24\ y)}{(70\ kg)}}{(25{,}550\ d)} \qquad (6)$$

Or, Chemical Ingestion Intake Factor = $2.99 \times 10^{-8}(d^{-1}) \times C(mg/kg)$.

<u>External Radiation Dose</u>

External Radiation Exposure Contact Rate =

$$= (C\ pCi/g)(8\ h/d)(7\ d/y)(30\ y)(0.8)(1.14x10^{-4}\ y/hr) \qquad (7)$$

Or, the external contact radiation dose = 0.153 (y) x C (pCi/g).

3.1.2 Noncarcinogenic Constituents

Noncarcinogenic effects are assessed using a HQ. As in the carcinogenic case, a PRG is back-calculated from a target HQ using the HSBRAM (DOE-RL 1993a). Table A-2 identifies the noncarcinogenic PRG. A HQ of 0.1 is used for individual constituents to adjust for possible synergistic and additive interactions between chemicals so that the sum of the HQ does not exceed 1.0 (DOE-RL 1994a). Noncarcinogenic effects of radionuclides are not calculated because the PRG are based on EPA derived reference doses (RfD). The EPA has not published RfD for radioactive elements (such as plutonium and uranium). In most cases, if not all, carcinogenic effects of radionuclides are expected to be of greater concern (i.e., risk) than noncarcinogenic effects.

The PRG calculation methodology follows the equations outlined in the HSBRAM (DOE-RL 1993a). All of the noncarcinogenic PRG calculations assumed ingestion of soil by a child, as outlined in HSBRAM (DOE-RL 1993a). In addition, the following general assumptions were made:

- RfD will be the same as provided for the QRA
- input parameters will be the same as those used in the QRA
- only ingestion of soils was considered in the PRG calculation. Inhalation RfD for most metals do not exist, and no dermal pathways were considered in the QRA.

3.2 ECOLOGICAL

Preliminary remediation goals are not estimated based on ecological receptors, because no methodology for the derivation of ecological PRG is currently agreed upon. Therefore, PRG protective of human health are adopted, for each of the zones of ecological receptor accessibility. Potential impacts of remediation on protected species, populations, communities, and ecosystems are addressed as part of the evaluation of FFS alternatives (Section 5.0).

3.3 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Applicable or relevant and appropriate requirements are federal or state promulgated standards defining acceptable levels for constituents or a method for determining an acceptable level. The ARAR applicable to this FFS are listed in Section 2.0. Of those ARAR and TBC, the only requirements with quantitative soil limits are the State of Washington's Model Toxics Control Act (MTCA) for chemicals and DOE Orders for radionuclides.

Model Toxics Control Act has a standard method (Method B) for determining acceptable levels for nonradioactive constituents. The method uses a residential exposure-scenario with a target risk of 1×10^{-6}. Model Toxics Control Act has not been defined by the decision makers as the ARAR which must be complied to, and it is only included as a potential state ARAR because it applies to a residential-scenario. However, it was used for comparison purposes in the *Feasibility Study Report for the 200-BP-1 Operable Unit*[1] (DOE-RL 1993b).

The values defined by MTCA will be more conservative than the risk-based calculations discussed in this paper due to the use of differing land-use scenarios. The MTCA values may be used in lieu of other sources of PRG.

The DOE Orders require limiting the dose from residual radioactivity to <100 mRem/yr. This requirement is considered a TBC, because the DOE Orders are not promulgated at this time; however, the DOE Orders are the only available source of soil limits and DOE has the authority to regulate radionuclides on DOE sites (one of which is Hanford). The dose limit of 100 mRem/yr represents a cumulative dose from contaminants, therefore is not used to determine PRG for individual contaminants.

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[1] The 200-BP-1 Operable Unit FS (DOE-RL 1993b) is the most recent FS conducted at Hanford. It considered in this FFS because the actions, location (i.e., Hanford), contaminants, available disposal facilities, and regulating agencies are all similar. Also, the 200-BP-1 FS has been reviewed by the regulating agencies, thus meets their expectations.

3.4 PROTECTION OF GROUNDWATER

Model Toxics Control Act defines default vadose zone concentrations which are protective of groundwater, as 100x the groundwater maximum contaminant levels (MCL) (WAC 173-340-740 (3)(A)). This default applies unless vadose zone modeling is employed to determine site-specific concentrations which protect groundwater. Because MTCA does not contain a comprehensive list of MCL for radionuclides, the Derived Concentration Guides (DCG) from the DOE's *Radiation Protection of the Public and the Environment* (DOE 1993) for radionuclides in groundwater are used to determine acceptable soil concentrations for radionuclides. The DCG are based on a 100 mrem/yr dose to offsite individual (from beta/gamma radiation).

Nonradionuclide groundwater MCL are derived from federally promulgated regulations such as the Safe Drinking Water Act (40 CFR 141), and the RCRA groundwater standards (40 CFR 264). Model Toxics Control Act groundwater MCL are used when a federal MCL is not available.

In place of the default MTCA 100x rule, this FFS uses an analytical model to determine soil concentrations that will be protective of groundwater. The analytical model used is the "Summers Method" which is documented in *Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water; A Compendium of Examples* (EPA 1989a). This method presents calculations that define acceptable soil concentrations from groundwater MCL (in this case, DCG for radionuclides). It differs from the MTCA 100x rule in that it uses site- and contaminant-specific parameters such as hydraulic conductivity, infiltration and soil distribution coefficients (Kd) (See Table A-3). The Summers Method is more rigorous than the 100x rule due to its use of site-specific conditions. The calculation performed for this FFS is also considered conservative because:

- the contaminant concentration is assumed to exist homogeneously throughout the vadose zone
- a conservative gradient (0.003 ft/day) is used
- groundwater mixing between site and point of compliance is not accounted for.

Allowable constituent concentrations in vadose zone soils are calculated using the following method:

$$Cs = Kd \times Cp \times (1.0 \text{ L}/1000 \text{ ml}) \qquad (9)$$

where:

Cp = allowable leachate concentration (pCi/l or ug/l)
Cs = soil concentration (pCi/g or mg/kg)
Kd = soil-water distribution coefficient (ml/g)

$$Cp = \frac{Cgw(Qp + Qgw) - Qgw*Ci}{Qp} \qquad (10)$$

where:

Cgw = allowable concentration in groundwater (MCL) (pCi/l or ug/l)
Qp = infiltration flow rate (ft^3/day), = Ap x q
Ap = horizontal area of contamination (ft^2)
q = recharge rate (ft/day)
Qgw = groundwater flow rate (ft^3/day), = V x h x w
V = Darcy velocity in groundwater (ft/day), = K x i
K = hydraulic conductivity of aquifer (ft/day)
i = hydraulic gradient in aquifer (ft/ft)
h = thickness of zone of mixing in aquifer (ft)
w = width of zone of mixing in aquifer (width of contaminated soil) (ft)
Ci = initial or background concentration in groundwater (pCi/l or ug/l)

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Using the value for the allowable concentration in groundwater, the leachate concentration is calculated. The soil concentration is then calculated using the appropriate distribution coefficient. For constituents where the distribution coefficient value is zero or does not exist, allowable soil concentrations are calculated as follows:

Cs = Cp x (m/d) x (1.0 mg/1000 ug or 1.0 kg/1000g) (11)

where:

m = volumetric moisture content (unitless)
d = soil dry density (kg/l)

For organic constituents, the Kd value is calculated from the following equation:

Kd = Koc x C (12)

where:

Koc = organic carbon partition coefficient (ml/gm)
C = fractional organic carbon content of soil (mass organic carbon/mass soil)

The following assumptions are made when calculating acceptable soil concentrations:

1. The aquifer is the Hanford/Ringold Formation. Average hydraulic conductivity is assumed to be 100 ft/day (DOE-RL 1993c).

2. The hydraulic gradient is estimated to be 0.003 ft/ft (DOE-RL 1993c).

3. Initial concentration in groundwater is assumed to be zero for all constituents, this is accurate for most radionuclides except for naturally occurring constituents.

4. Zone of mixing is 30 ft thick (Hartman and Lindsey 1993).

5. Recharge rate is 10 cm/yr (Gee 1987).

6. Allowable concentration in groundwater is the DCG for radionuclides; a combination of primary MCL, secondary MCL, and RCRA groundwater standards for nonradionuclides; and MTCA groundwater MCL when a federal standard is not available.

7. Distribution coefficients for radionuclides and inorganics are as documented in Ames and Serne (1991).

8. Soil moisture content averages about 5% (9% by volume) (DOE-RL 1994b).

9. Soil dry density is about 110 pcf (1.8 kg/l).

10. Organic carbon of Hanford soil is 0.1% by weight (Ames and Serne 1991).

11. Organic carbon partitioning coefficients for organics are as documented in EPA (1986).

12. Waste site area is assumed to be that of the 116-C-5 retention basins (800 x 800 ft) or (640,000 ft^2).

Using the above stated assumptions the allowable soil concentration for cesium-137 can be calculated as follows:

First calculated Cp;

Cgw = 1146 pCi/l
Qp = (800 ft * 0.0009 ft/day) = 575 ft^3/day
Qgw = (100 ft/day * 0.003) * 30 ft * 800 ft = 7200 ft^3/day
Ci * Qgw = 0

Cp = 1146 pCi/l * (575 + 7200 ft^3/day)/575 ft^3/day - 15,500 pCi/l

Then calculate Cs;

Kd = 50 ml/g
Cs = 50 ml/g * 15,500 pCi/l * 1.01/1000 ml = 775 pCi/g.

The above description of the Summers Method defines protectiveness of groundwater and is used to aid in delineating which sites may need remedial action. For general response actions involving in situ action, the allowable soil concentrations which are protective of groundwater will change as the environment is altered and the parameters used to calculate protectiveness numbers change. The in situ technology evaluated in this FFS requiring reevaluation of the Summers Method is the surface barrier. The surface barrier reduces the amount of infiltration available to the vadose zone at the site and permits a less stringent PRG. For this option it is assumed that only 0.5 mm of infiltration reaches groundwater.

The allowable soil concentrations under this reduced infiltration scenario are presented in Table A-4. If these levels are exceeded at a given waste site then the in situ option will not be protective of groundwater.

3.5 BACKGROUND

Background concentrations are considered the lowest practical levels for a cleanup action. Even though the objective of any remedial action is to achieve levels protective of human health and the environment, it is only realistic to consider cleanup to local background concentrations.

Background investigations for nonradioactive constituents have been completed and are documented in *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analyses* (DOE-RL 1993d). The study has produced statistical distributions of background concentrations for nonradioactive constituents. The appropriate confidence limit for the distribution of background data for use in the IRM will be documented in the Interim Record of Decision (IROD). The 95% upper threshold limit for inorganic constituents is presented in Table A-5.

Characterization of radioactive constituents is in progress and values should be available at the time the IROD is written. The preliminary radionuclide values are presented in Table A-6. When considering the radionuclide background data presented in Table A-6, it should be noted that the data is very sparse for some isotopes, both in number and in geographic coverage. The means and standard deviations have been computed from data collected by PNL during the years 1987 through 1991 (e.g., Environmental Data for Calendar Year 1991, Surface and Columbia River; PNL - 8149), a few are from 1992. Most of the samples were collected on the Hanford Site, but a few are from distant locations, such as Moses Lake, Yakima, and Walla Walla. Only offsite, distant data were used to compute these preliminary statistics. also, the thorium-232 preliminary background number is very tentative since it is based on only three samples.

3.6 CONTRACT REQUIRED QUANTITATION LIMITS OR CONTRACT REQUIRED DETECTION LIMITS

Contract required laboratory detection limits for each COPC will be used for the PRG if all other potential PRG values are below required levels of detection (see Table A-2).

This is in agreement with MTCA which states that (WAC 173-340):

> "...cleanup levels for hazardous substances not addressed under applicable state and federal laws...are established at concentrations which do not exceed the natural background concentration or the practical quantitation limit for the substance in question."

Also, EPA's risk assessment guidance (EPA 1989b) states that use of contract required quantitation limit (CRQL)/contract required detection limit (CRDL) as limits to PRG should be considered after contaminants are verified as legitimate and the responsible parties have negotiated to obtain lower limits such as using special analytical services before investigation. The CRQL/CRDL used in determining the PRG are:

- based on COPC. The contaminants used in the FFS have been through data validation, screening in the QRA, and screening in the LFI before being placed on the COPC list, thus they are legitimate contaminants.

- taken from operable unit-specific work plans (see Table A-2). The Tri-Parties negotiated and approved the work plans which define CRQL/CRDL. These CRQL/CRDL are used in the FFS as an element of the PRG.

4.0 APPLICATION OF PRG VALUES

Within each zone, there may be PRG values available for more than one receptor. In all cases, the most stringent value is used as the PRG for a given constituent in a given zone. It is understood however that the PRG value must not be below background concentrations and must be above detection limits. Table A-2 identifies the PRG for each constituent in each zone (note that background values are not represented because no single set of background concentrations has been identified for the 100 Area soils). Once background values are identified this table will be reevaluated.

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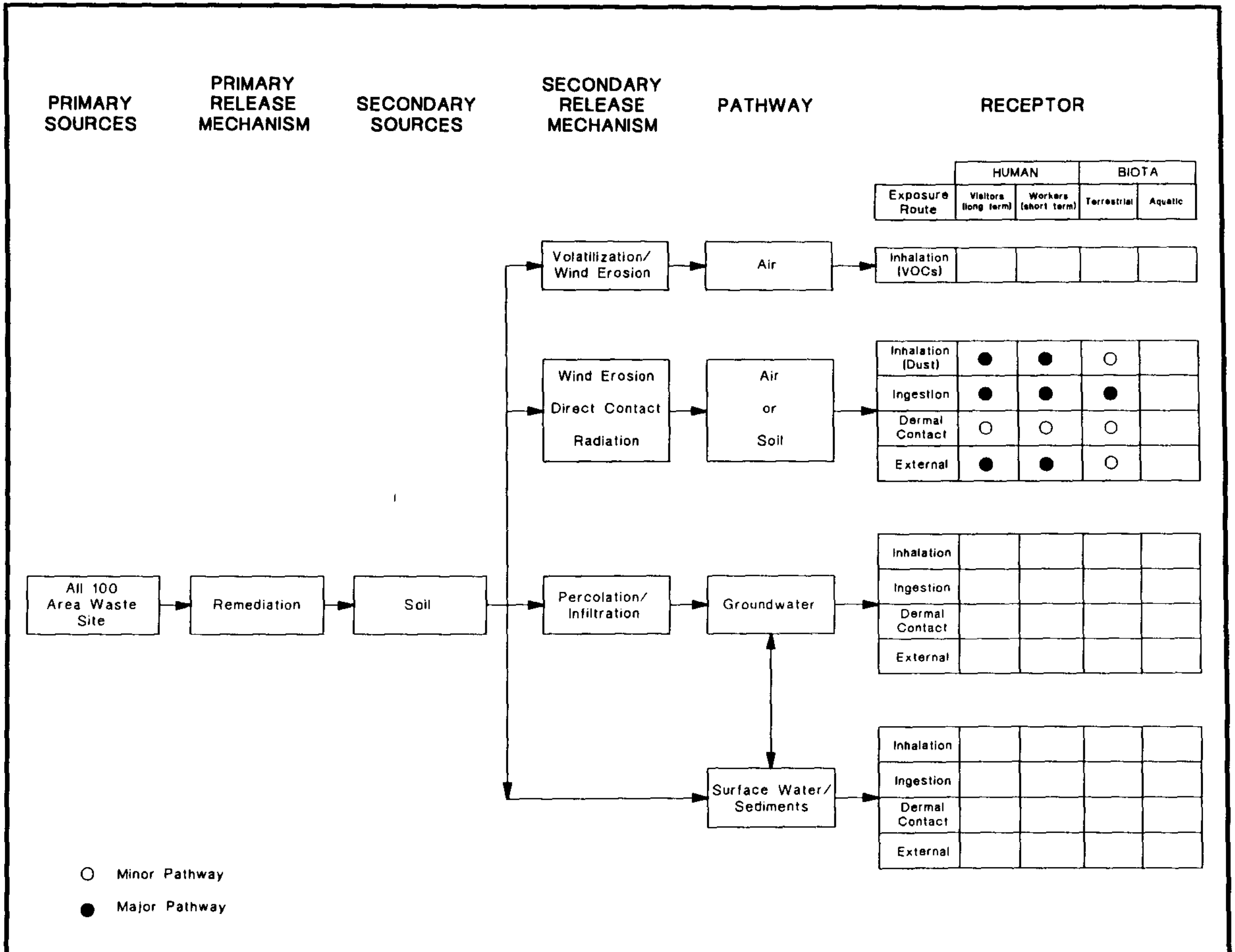

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Figure A-1 100 Area Source Operable Unit FFS Conceptual Exposure Pathway Model

Table A-1 Zones of Receptor Accessibility

Zone	Depth (m)	Receptor	Exposure Pathway	Potential PRG
1	0-1	Humans	ingestion, inhalation, and exposure to external radiation	Human health Plant-specific Animal-specific ARAR Protection of GW CRDL/CRQL Background
		Plants	uptake from soil into biomass	
		Animals	ingestion of plants	
2	1-2	Plants	uptake from soil into biomass	Plant-specific Animal-specific ARAR Protection of GW CRDL/CRQL Background
		Animals	ingestion of plants	
3	2-3	Plants	uptake from soil into biomass	Plant-specific ARAR Protection of GW CRDL/CRQL Background
4	3-GW	Protection of groundwater resource		Protection of GW CRDL/CRQL Background

PRG - preliminary remediation goals
ARAR - applicable, relevant and appropriate requirements
GW - groundwater
CRDL - contract required detection limits
CRQL - contract required quantitation limits

Table A-2 Potential Preliminary Remediation Goals

	HUMAN HEALTH		ECOLOGICAL (a)		Protection of Groundwater (b)	CRQL/ CRDL (c)	ZONE SPECIFIC PRG			
	TR = 1E-06(g)	HQ = 0.1	Mouse	Plant			ZONE 1 0-3 ft	ZONE 2 3-6 ft	ZONE 3 6-10 ft	ZONE 4 >10 ft
RADIONUCLIDES (pCi/g)										
Am-241	76.9	N/A	NC	NC	31	1	31	31	31	31
C-14	44200	N/A	NC	NC	18	50	50	50	50	50
Cs-134	3460	N/A	NC	NC	517	0.1 (h)	517	517	517	517
Cs-137	5.68	N/A	NC	NC	775	0.1	5.68	5.68	5.68	775
Co-60	17.5	N/A	NC	NC	1292	0.05	17.5	17.5	17.5	1292
Eu-152	5.96	N/A	NC	NC	20667	0.1	5.96	5.96	5.96	20667
Eu-154	10.6	N/A	NC	NC	20667	0.1	10.6	10.6	10.6	20667
Eu-155	3080	N/A	NC	NC	103333	0.1	3080	3080	3080	103333
H-3	2900000	N/A	NC	NC	517	400	517	517	517	517
K-40	12.1	N/A	NC	NC	145	4 (i)	12.1	12.1	12.1	145
Na-22	545	N/A	NC	NC	207	4 (i)	207	207	207	207
Ni-63	184000	N/A	NC	NC	46500	30	46500	46500	46500	46500
Pu-238	87.9	N/A	NC	NC	5	1	5	5	5	5
Pu-239/240	72.8	N/A	NC	NC	4	1	4	4	4	4
Ra-226	1.1	N/A	NC	NC	0.03	0.1	0.1	0.1	0.1	0.1
Sr-90	1930	N/A	NC	NC	129	1	129	129	129	129
Tc-99	28900	N/A	NC	NC	26	15	26	26	26	26
Th-228	7260	N/A	NC	NC	0.103	1 (d)	1	1	1	1
Th-232	162	N/A	NC	NC	0.013	1	1	1	1	1
U-233/234	165	N/A	NC	NC	5	1	5	5	5	5
U-235	23.6	N/A	NC	NC	6	1	6	6	6	6
U-238 (e)	58.4	N/A	NC	NC	6	1	6	6	6	6
INORGANICS (mg/kg)										
Antimony	N/A	167	NC	NC	0.002	6	6	6	6	6
Arsenic	16.2	125	NC	NC	0.013	1	1	1	1	1
Barium	N/A	29200	NC	NC	258	20	258	258	258	258
Cadmium	1360	417	NC	NC	0.775	0.5	0.775	0.775	0.775	0.775
Chromium VI	204	2086	NC	NC	0.026	1	1	1	1	1
Lead	N/A	N/A	NC	NC	8	0.3	8	8	8	8
Manganese	N/A	2086	NC	NC	13	1.5	13	13	13	13
Mercury	N/A	125	NC	NC	0.31	0.02	0.31	0.31	0.31	0.31
Zinc	N/A	100000 (f)	NC	NC	775	2	775	775	775	775
ORGANICS (mg/kg)										
Aroclor 1260 (PCB)	4.34	N/A	NC	NC	1.37	0.033	1.37	1.37	1.37	1.37
Benzo(a)pyrene	N/A	N/A	NC	NC	5.68	0.33	5.68	5.68	5.68	5.68
Chrysene	N/A	N/A	NC	NC	0.01	0.33	0.33	0.33	0.33	0.33
Pentachlorophenol	N/A	N/A	NC	NC	0.27	0.8	0.8	0.8	0.8	0.8

N/A= NOT APPLICABLE
NC=NOT CALCULATED. Appropriate calculation not established at this time.
TR=Target Risk
HQ=Hazard Quotient
(a)=Human health values used in zones 2 and 3 if Ecological values are not calculated.
(b)=Based on Summer's Model (EPA 1989b)
(c)=Based on 100-BC-5 OU Work Plan QAPjP (DOE-RL 1992)
(d)=Detection limit assumed to be same as Th-232
(e)=Includes total U if no other data exist
(f)=Value calculated exceeds 1,000,000 ppm therefore use 100,000 ppm as default
(g)=Recreational exposure scenario accounting for decay to 2018
(h)=Detection limit assumed to be same as Cs-137
(i)=Based on gross beta analysis

Table A-3 Kd Values Used in the Summer's Method

Radionuclides	Kd (ml/g)	Inorganics	Kd (ml/g)	Organics	Kd (ml/g)
^{241}Am	200	Antimony	0.05	Aroclor 1260	530
^{14}C	0.05	Arsenic	0.05	Benzo(a)pyrene	5,500
^{134}Cs	50	Barium	25	Chrysene	200
^{137}Cs	50	Cadmium	30	Pentachlorophenol	53
^{60}Co	50	Chromium VI	0.05		
^{152}Eu	200	Lead	30		
^{154}Eu	200	Manganese	50		
^{155}Eu	200	Mercury	30		
^{3}H	0.05	Zinc	30		
^{40}K	4				
^{22}Na	4				
^{63}Ni	30				
^{238}Pu	25				
$^{239/240}Pu$	25				
^{226}Ra	0.05				
^{90}Sr	25				
^{99}Tc	0.05				
^{228}Th	0.05				
^{232}Th	0.05				
$^{233/234}U$	2				
^{235}U	2				
^{238}U	2				

Table A-4 Allowable Soil Concentration - Reduced Infiltration Scenario

Analyte	Soil Concentration
RADIONUCLIDES	**pCi/g**
^{241}Am	5,012
^{14}C	2,924
^{134}Cs	83,539
^{137}Cs	125,309
^{60}Co	208,848
^{152}Eu	3,341,560
^{154}Eu	3,341,560
^{155}Eu	16,707,800
^{3}H	83,539
^{40}K	23,391
^{22}Na	33,416
^{63}Ni	7,518,510
^{238}Pu	835
$^{239/240}$Pu	627
^{226}Ra	4
^{90}Sr	20,885
^{99}Tc	4,177
^{228}Th	16.708
^{232}Th	2.088
$^{233/234}$U	835
^{235}U	1,002
^{238}U	1,002
INORGANICS	**mg/kg**
Antimony	0.251
Arsenic	2.088
Barium	41,770
Cadmium	125.309
Chromium (VI)	4.177
Lead	1,253
Manganese	2,088
Mercury	50.123
Zinc	125,309
ORGANICS	**mg/kg**
Aroclor 1260	221
Benzo(a)pyrene	919
Chrysene	2
Pentachlorophenol	44

Table A-5 Summary Statistics and Upper Threshold Limits for Inorganic Analytes

Analyte	95% UTL[a](mg/kg)
Aluminum	15,600
Antimony	15.7[b]
Arsenic	8.92
Barium	171
Beryllium	1.77
Cadmium	0.66[b]
Calcium	23,920
Chromium	27.9
Cobalt	19.6
Copper	28.2
Iron	39,160
Lead	14.75
Magnesium	8,760
Manganese	612
Mercury	1.25
Nickel	25.3
Potassium	3,120
Selenium	5[b]
Silver	2.7
Sodium	1,290
Thallium	3.7[b]
Vanadium	111
Zinc	79
Molybdenum	1.4[b]
Titanium	3,570
Zirconium	57.3
Lithium	37.1
Ammonia	28.2
Alkalinity	23,300
Silicon	192
Fluoride	12
Chloride	763
Nitrite	21[b]
Nitrate	199
Ortho-phosphate	16
Sulfate	1,320

Source: DOE-RL 1993d, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*, DOE/RL-92-24, Rev. 1 Draft, U.S. Department of Energy, Richland, Washington.
[*] NR = Not Reported
[a] 95% confidence limit of the 95th percentile of the data distribution
[b] Limit of detection

Table A-6 Preliminary Background Concentrations for Radionuclides in Soil

Analyte	Ave + 2*SD (a)	Number of Samples	Comments
Sitewide background, man-made isotopes (pCi/g)			
^{241}Am	NR	NA	Not Analyzed
^{60}Co	0.024	3	ML, YK, Most below detection
^{134}Cs	0.081	16	Some data from all 9 sites. All near or below detection
^{137}Cs	1.08	48	All data from all 9 sites
^{152}Eu	NR	NA	Not Analyzed
^{154}Eu	0.19	2	ML; rest are below detection
^{155}Eu	0.15	13	OT, BC, ML, WA, WW, SS, YK. Most below detection
^{238}Pu	0.003	27	Some data from all 9 sites. All near or below detection
$^{239/240}$Pu	0.021	47	All data from all 9 sites
^{90}Sr	0.29	49	All data from all 9 sites
^{233}U	No Data	NA	Not Analyzed
Sitewide background, natural isotopes (pCi/g)			
^{40}K	20.2	49	All data from all 9 sites
^{226}Ra	.94	27	All data from all 9 sites
^{232}Th	1.1	3	ML, WA, YK
^{234}U	0.82	12	All data from all 9 sites
^{235}U	0.04	11	All data from all 9 sites
^{238}U	0.8	12	All data from all 9 sites
^{Nat}U	0.62	16	All data from all 9 sites

(a) = based on data collected by PNL 1987 through 1991
NR = not reported
NA = not applicable
SD = standard deviation

Site abbreviations
BC = Benton City
CO = Connell
MD = McNary Dam
ML = Moses Lake
OT = Othello
SS = Sunnyside
YK = Yakima
WW = Walla Walla
WA = Washtucna

APPENDIX B

WASTE SITE GROUP COST ESTIMATES

1.0 COST ESTIMATE SUMMARIES

There are two primary purposes of this appendix. The first to provide a discussion on the methods used to develop the cost models in support of the source operable unit focused feasibility study reports. The second is to apply the cost models to the remedial alternatives for each waste site group and present them in summary form on the attached tables.

The cost models are developed using the Environmental Restoration cost models (1994 fiscal year planning baselines) as the starting point. These Environmental Restoration cost models were revised for the focused feasibility studies to include all costs associated with the remedial alternatives. Project Time and Cost, Inc., supported both the baseline and focused feasibility study cost estimating activities. These models are presented in detail in *100 Area Source Operable Unit Focused Feasibility Study Cost Models* (WHC 1994). The Cost Model document (WHC 1994) also provides a description of the work breakdown structure and general assumptions for each cost model.

The cost model are first used to support the cost estimates for the waste site groups discussed in this document. An estimate is run for each waste site group based on the applicable remedial alternatives. These estimates are presented in Tables B-1 through B-8. The corresponding Figures B-1 through B-8 graphically represent the estimates with a variation in the disposal unit cost. The figure contains three data points for the disposal unit cost: $70/cubic yard (the design point), $700/cubic yard. The design point ($70/cubic yard) is based on current estimates for initial construction, operations/maintenance, and anticipated expansion. Future use of the cost models will occur in each operable unit-specific focused feasibility study.

Waste Site Group	Cost Summary Table	Cost Summary Figure
Retention Basins	Table B-1	Figure B-1
Sludge Trenches	Table B-2	Figure B-2
Fuel Storage Basin Trenches	Table B-3	Figure B-3
Process Effluent Trenches	Table B-4	Figure B-4
Pluto Cribs	Table B-5	Figure B-5
Dummy Decontamination Cribs and French Drains	Table B-6	Figure B-6
Seal Pit Cribs	No Costs Associated	No Costs Associated
Pipelines	Table B-7	Figure B-7
Burial Grounds	Table B-8	Figure B-8
Decontaminated and Decommissioned Facilities	No Costs Associated	No Costs Associated

2.0 REFERENCES

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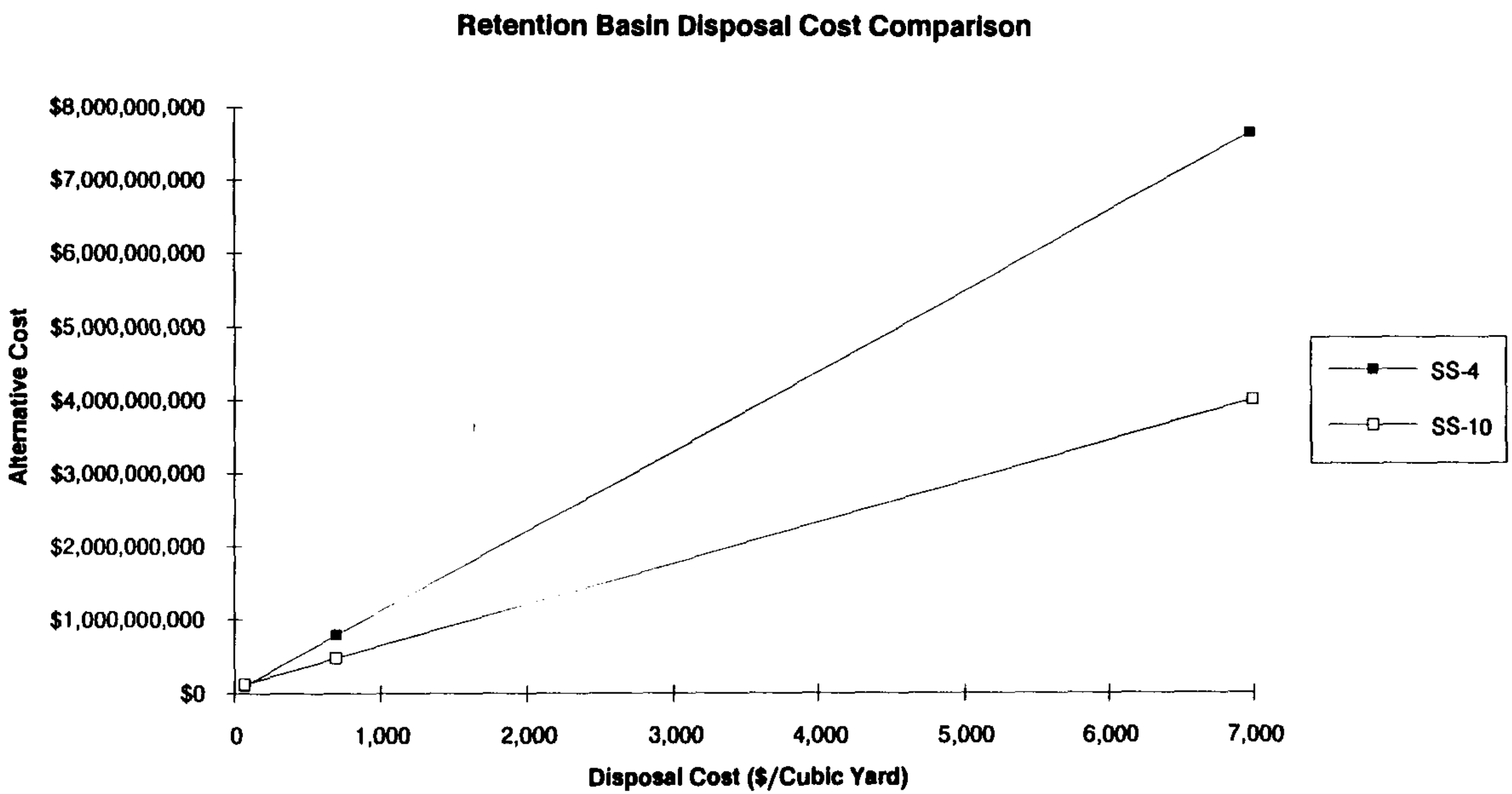


Figure B-1 Retention Basins Disposal Cost Comparison

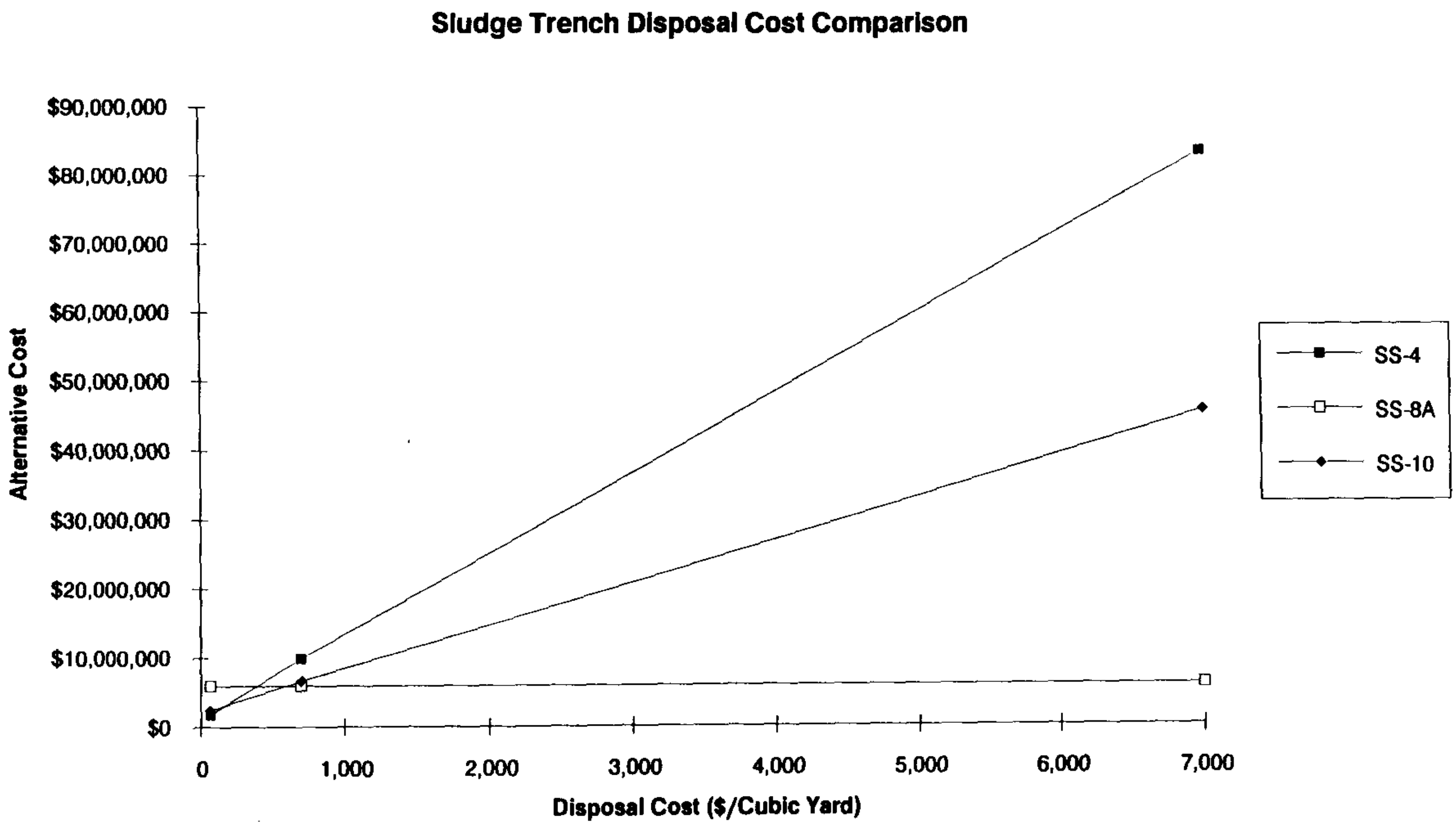


Figure B-2 Sludge Trenches Disposal Cost Comparison

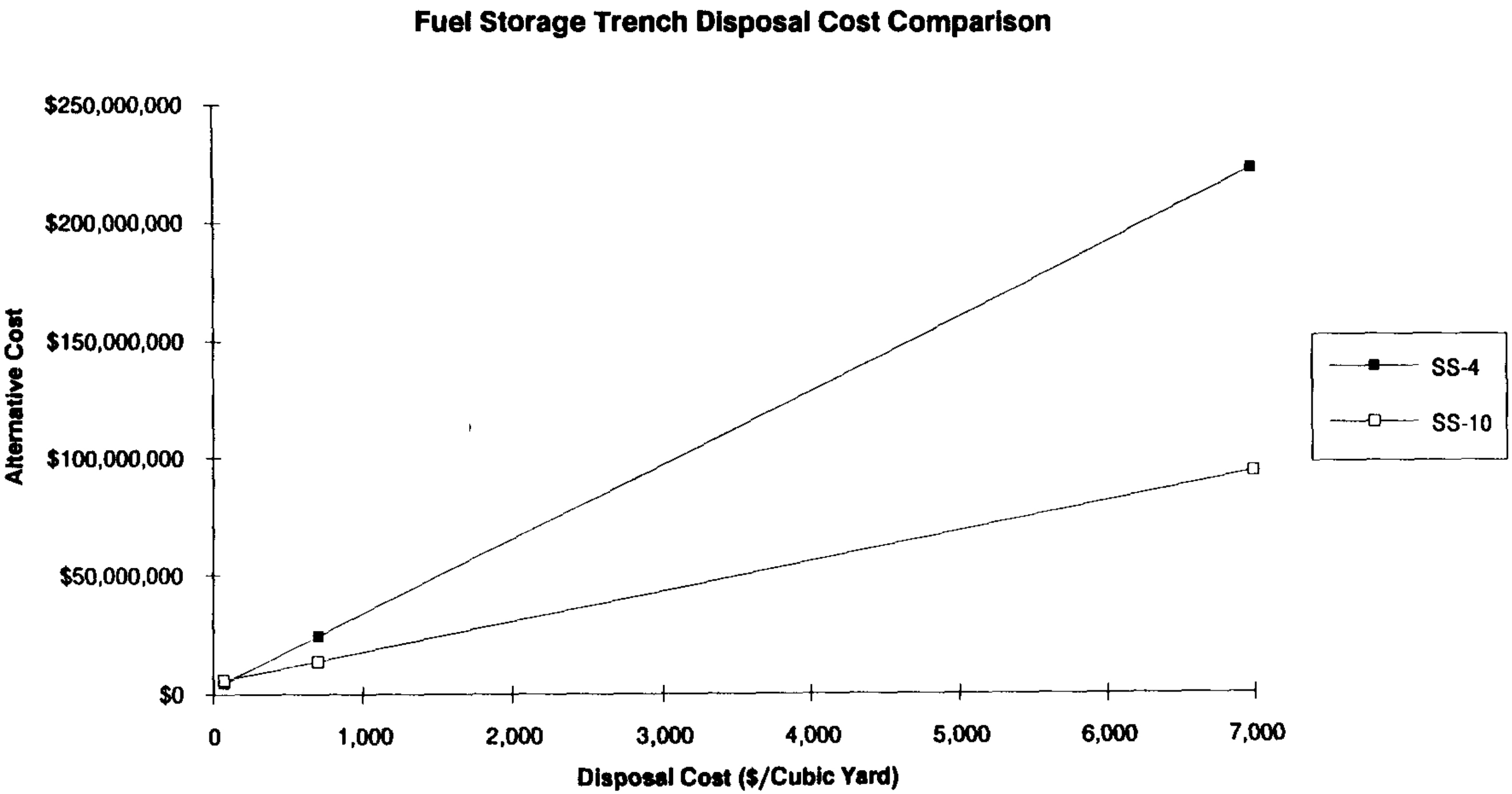


Figure B-3 Fuel Storage Basin Trenches Disposal Cost Comparison

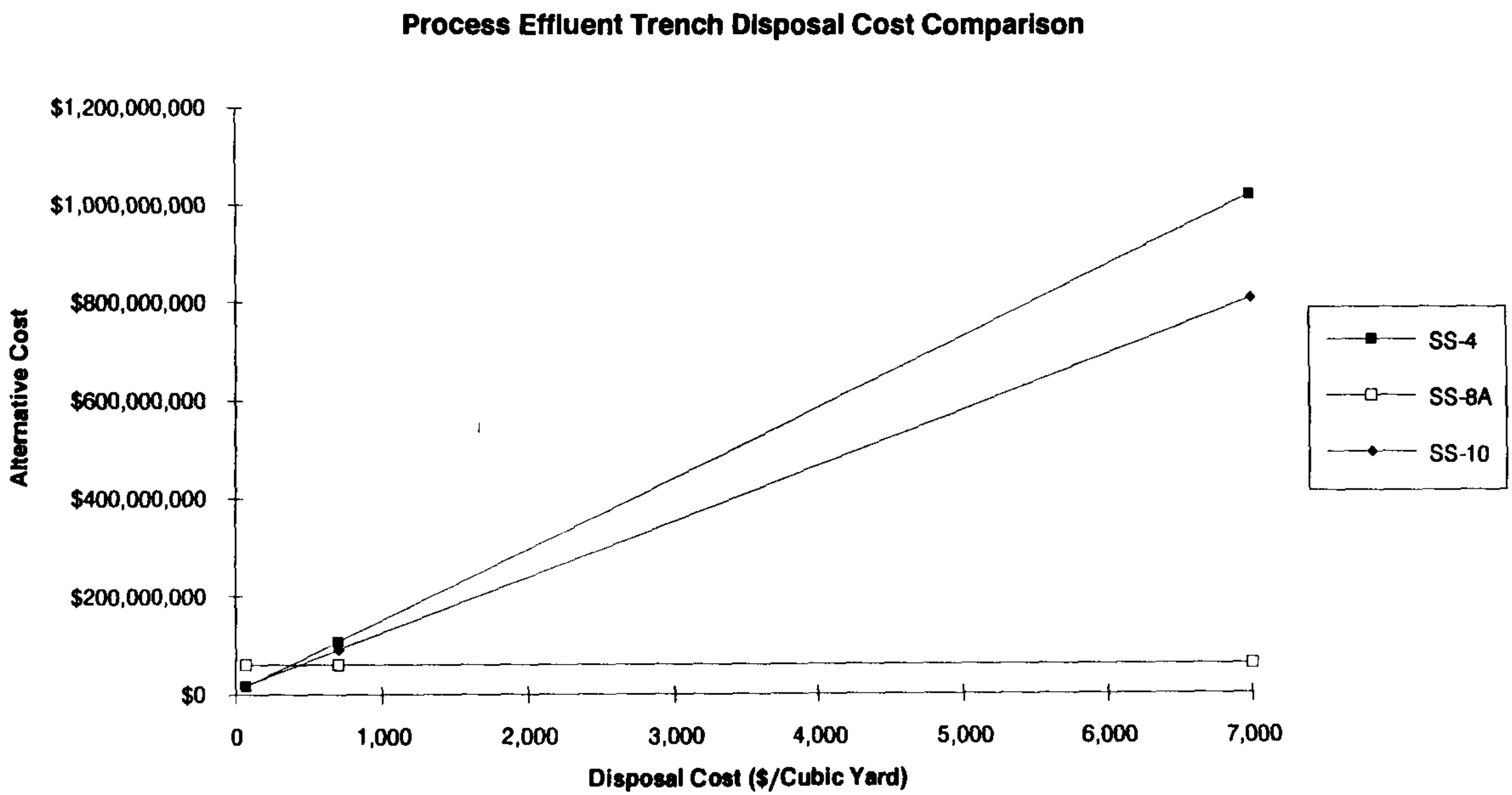
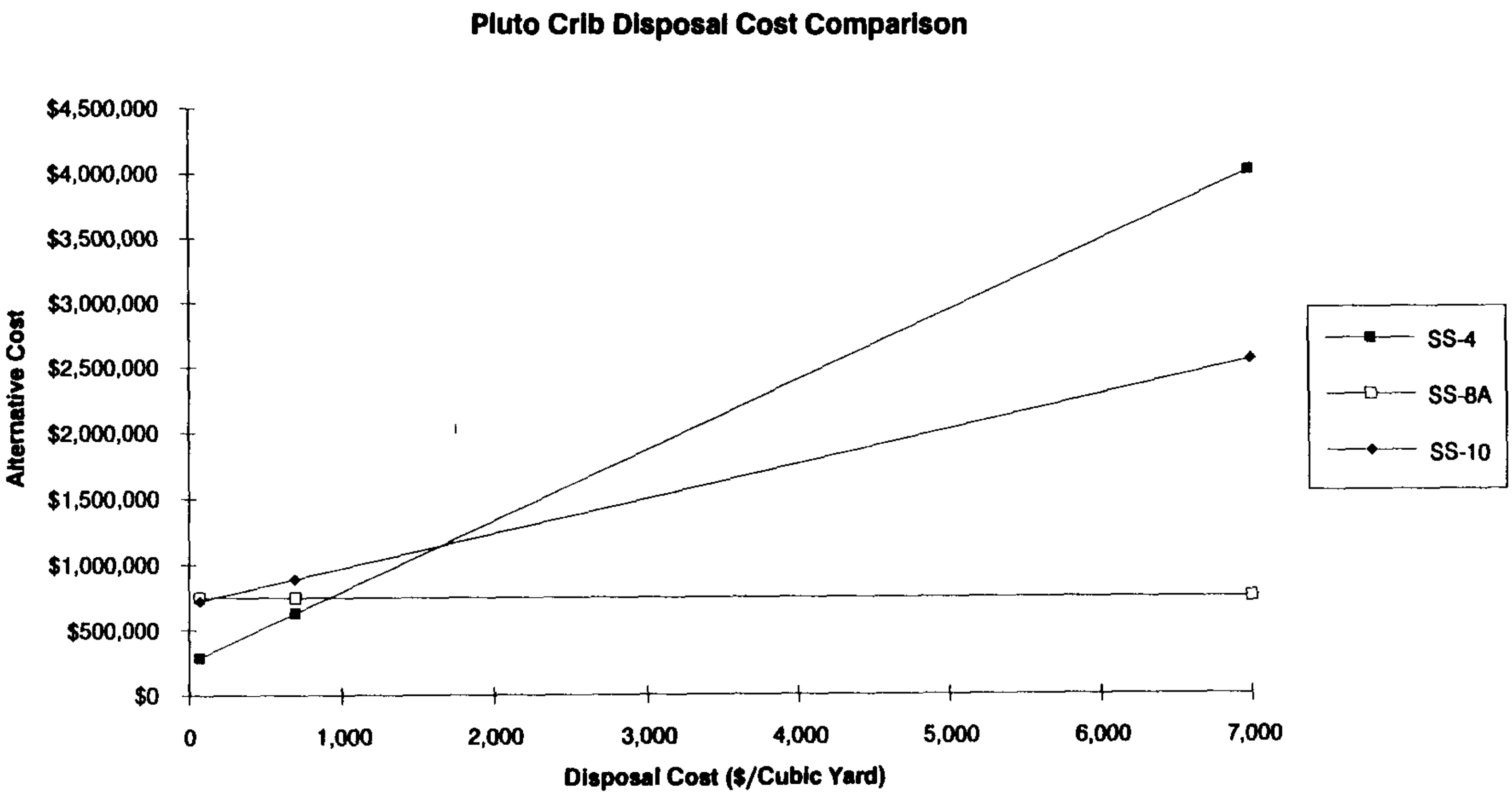


Figure B-4 Process Effluent Trenches Disposal Cost Comparison

Figure B-5 Pluto Cribs Disposal Cost Comparison



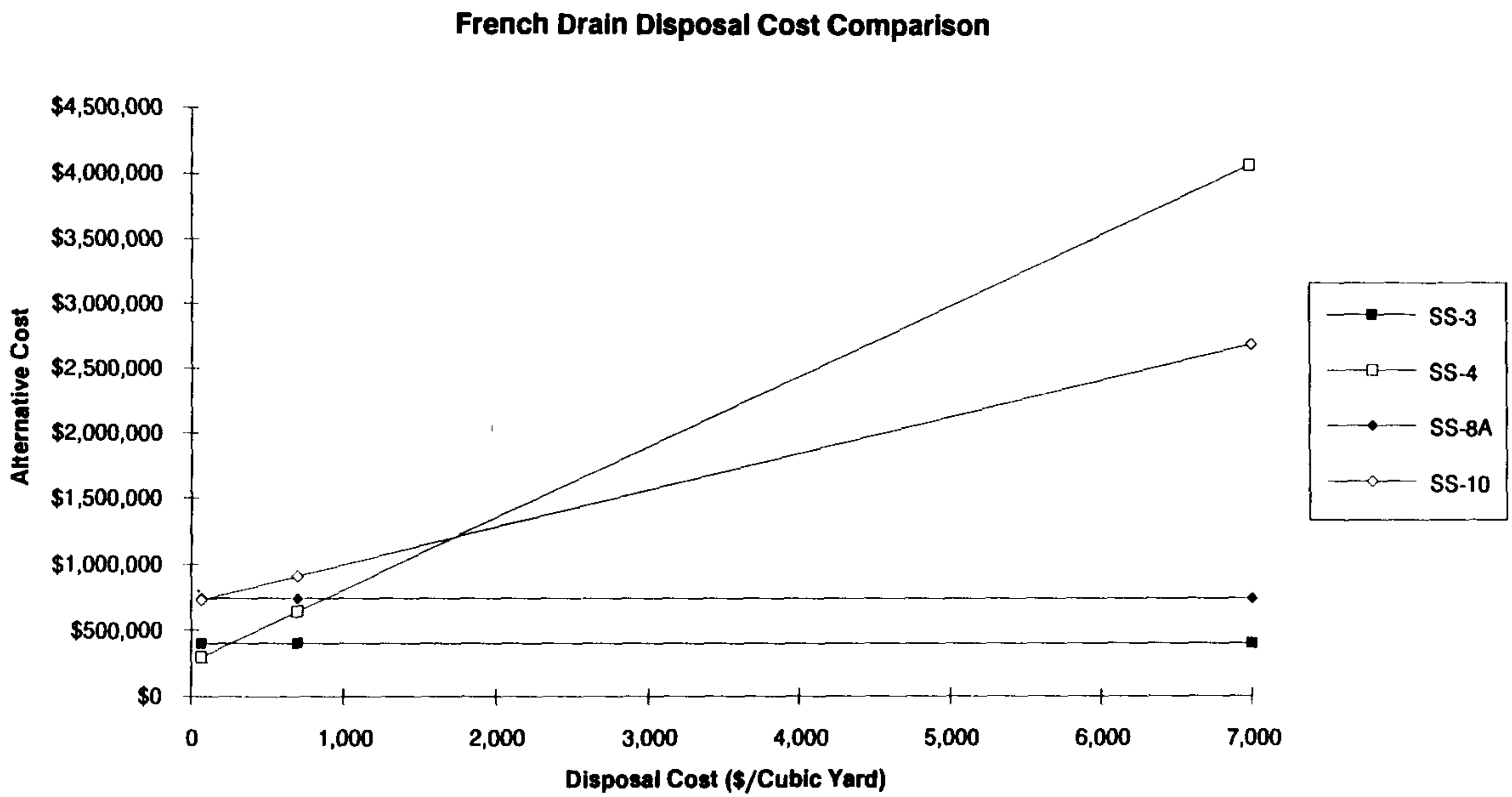


Figure B-6 Dummy Decontamination Cribs and French Drains Disposal Cost Comparison

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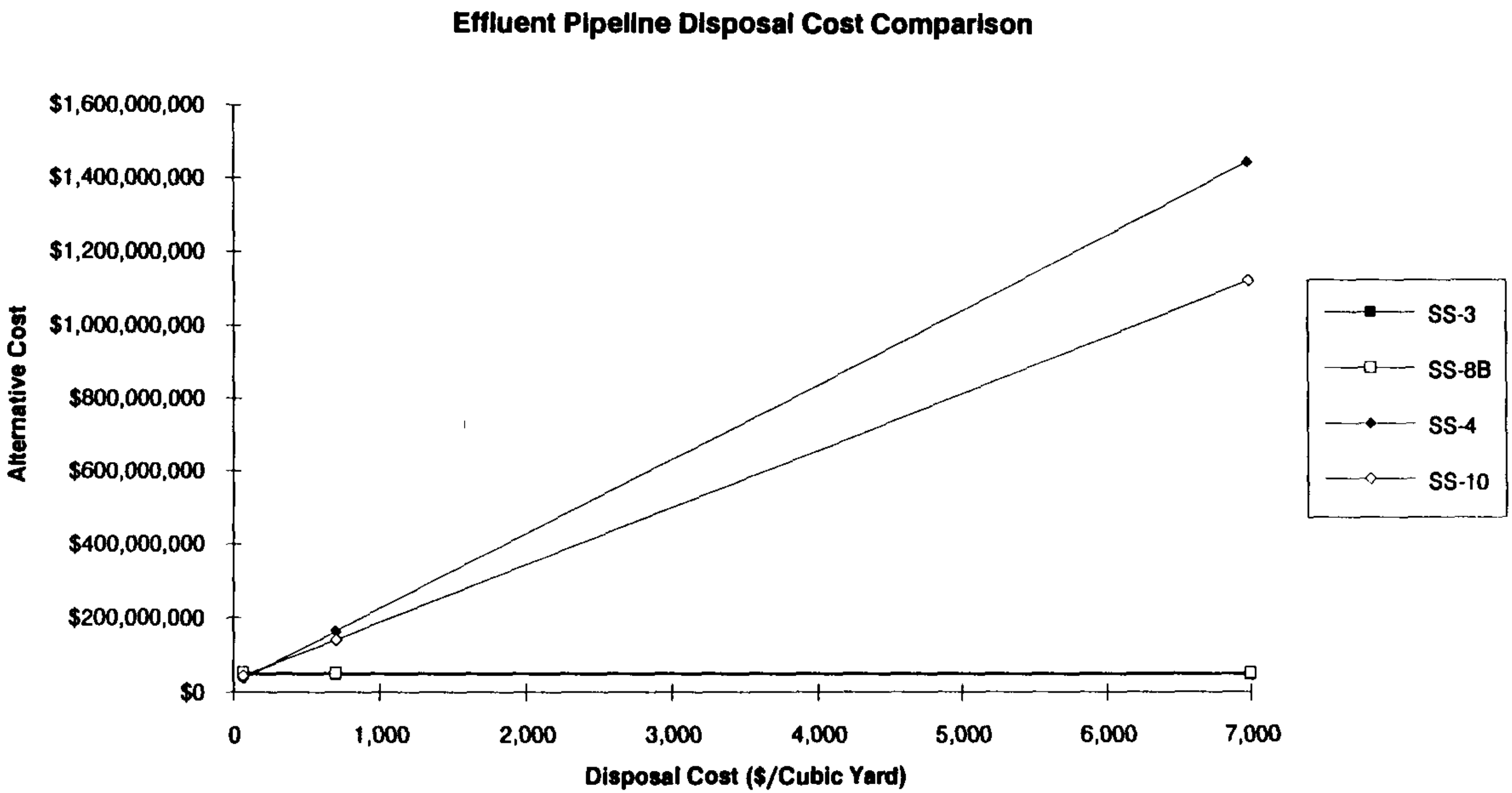

Figure B-7 Pipelines Disposal Cost Comparison

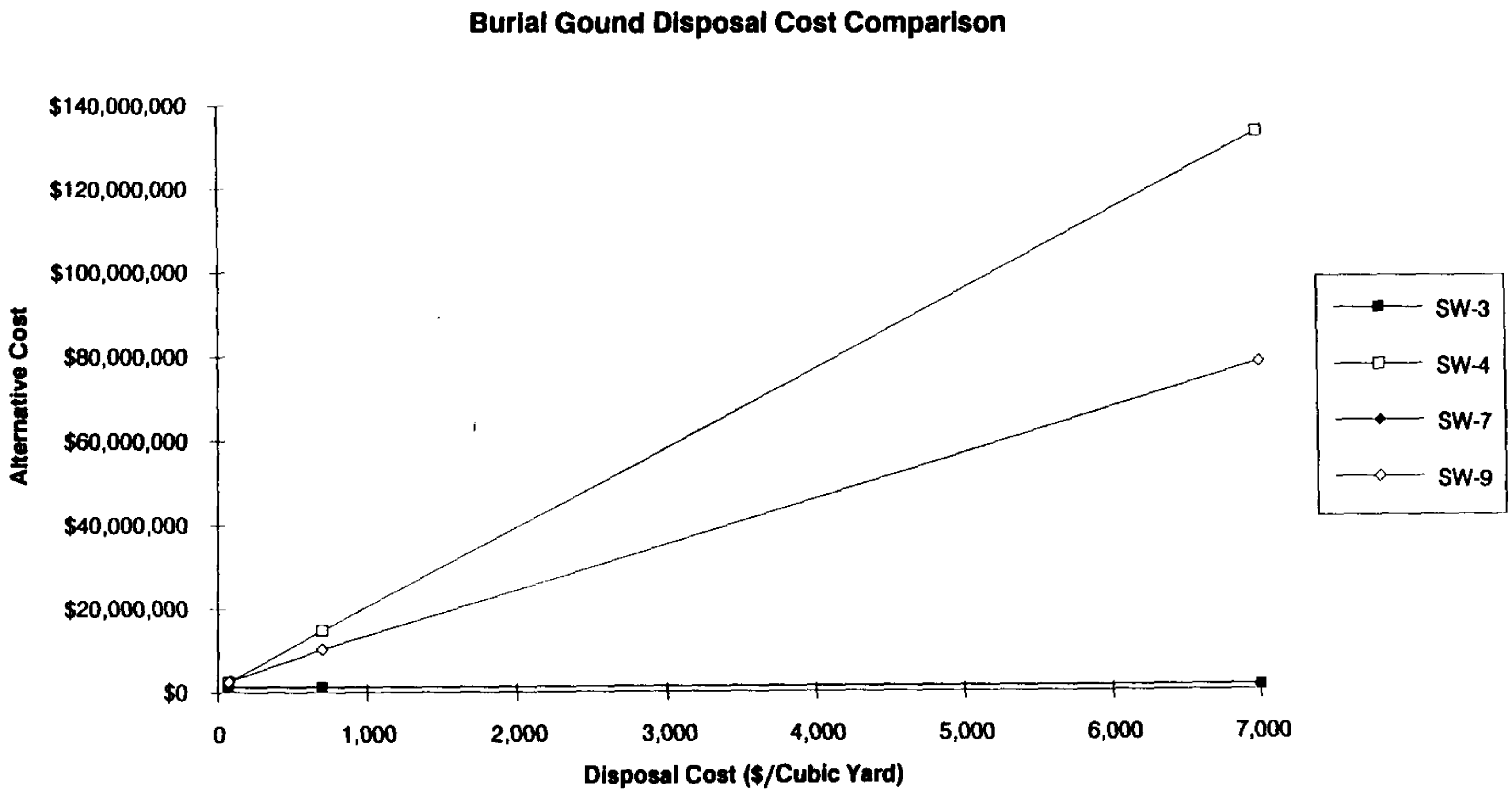

Figure B-8 Burial Grounds Disposal Cost Comparison

Table B-1 Cost Summary for Retention Basins

Cost Element		SS-4	SS-10
ANA: Offsite Analytical Services			
ANA:02	Monitoring, Sampling & Analysis	896,730	2,791,230
SUB: Fixed Price Contractor			
SUB:01	Mobilization & Preparatory	98,320	86,895
SUB:02	Monitoring, Sampling & Analysis	655,060	1,687,645
SUB:08	Solids Collection & Containment	1,488,360	2,701,331
SUB:13	Physical Treatment		24,631,614
SUB:18	Disposal(Other than Commercial)	42,082,870	23,978,104
SUB:20	Site Restoration	5,429,140	4,582,906
SUB:21	Demobilization	19,930	17,686
WHC: Westinghouse Hanford Company			
WHC:02	Monitoring, Sampling & Analysis	1,138,810	3,252,496
WHC:08	Solids Collection & Containment	117,830	367,196
Subcontractor Materials Procurement Rate		497,740	576,862
Project Management/Construction Management		7,729,210	9,282,410
General & Admin/Common Support Pool		15,110,600	18,147,112
Contingency		27,095,250	34,078,290
Total		102,359,830	126,181,775
Capital		102,359,830	101,704,269
Annual Operations & Maintenance		0	7,649,221
Present Worth		95,988,999	113,522,862

SS-3/SW-3: Containment
SS-4/SW-4: Removal/Disposal
SS-8A/SS-8B/SW-7: In Situ Treatment
SS-10/SW-9: Removal/Treatment/Disposal

Table B-2 Cost Summary for Sludge Trenches

Cost Element		SS-4	SS-8A	SS-10
ANA: Offsite Analytical Services				
ANA:02	Monitoring, Sampling & Analysis	54,730	-	84,200
SUB: Fixed Price Contractor				
SUB:01	Mobilization & Preparatory	52,930	50,880	58,720
SUB:02	Monitoring, Sampling & Analysis	22,070	10,370	29,110
SUB:08	Solids Collection & Containment	49,220	30,350	54,230
SUB:13	Physical Treatment	-	-	436,620
SUB:14	Thermal Treatment	-	-	-
SUB:15	Stabilization/Fixation	-	2,425,230	-
SUB:18	Disposal (Other than Commercial)	476,830	-	270,280
SUB:20	Site Restoration	132,560	93,660	114,200
SUB:21	Demobilization	13,890	13,960	13,890
WHC: Westinghouse Hanford Company				
WHC:02	Monitoring, Sampling & Analysis	58,900	205,630	101,880
WHC:08	Solids Collection & Containment	4,220	31,650	8,790
Subcontractor Materials Procurement Rate		54,570	191,580	71,320
Project Management/Construction Management		129,780	458,000	173,850
General & Admin/Common Support Pool		253,710	895,380	339,880
Contingency		443,160	1,498,270	650,070
Total		1,746,550	5,904,950	2,407,030
Capital		1,746,550	3,614,830	2,130,290
Annual Operations & Maintenance		0	2,290,120	276,740
Present Worth		1,665,934	5,630,268	2,302,000

SS-3/SW-3: Containment
SS-4/SW-4: Removal/Disposal
SS-8A/SS-8B/SW-7: In Situ Treatment
SS-10/SW-9: Removal/Treatment/Disposal

Table B-3 Cost Summary for Fuel Storage Basin Trenches

Cost Element		SS-4	SS-10
ANA: Offsite Analytical Services			
ANA:02	Monitoring, Sampling & Analysis	134,720	202,080
SUB: Fixed Price Contractor			
SUB:01	Mobilization & Preparatory	48,220	54,020
SUB:02	Monitoring, Sampling & Analysis	90,500	109,850
SUB:08	Solids Collection & Containment	197,440	210,690
SUB:13	Physical Treatment	-	1,110,490
SUB:14	Thermal Treatment	-	-
SUB:15	Stabilization/Fixation	-	-
SUB:18	Disposal (Other than Commercial)	1,296,360	591,070
SUB:20	Site Restoration	327,910	265,790
SUB:21	Demobilization	13,220	13,210
WHC: Westinghouse Hanford Company			
WHC:02	Monitoring, Sampling & Analysis	195,830	261,770
WHC:08	Solids Collection & Containment	16,880	21,450
Subcontractor Materials Procurement Rate		144,080	171,920
Project Management/Construction Management		349,570	421,540
General & Admin/Common Support Pool		683,410	824,110
Contingency		1,189,370	1,575,460
Total		4,687.520	5,833,480
Capital		4,687,520	4,883,100
Annual Operations & Maintenance		0	950,380
Present Worth		4,466,689	5,565,137

SS-3/SW-3: Containment
SS-4/SW-4: Removal/Disposal
SS-8A/SS-8B/SW-7: In Situ Treatment
SS-10/SW-9: Removal/Treatment/Disposal

Table B-4 Cost Summary for Process Effluent Trenches

Cost Element		SS-4	SS-8A	SS-10
ANA: Offsite Analytical Services				
ANA:02	Monitoring, Sampling & Analysis	298,910	-	564,140
SUB: Fixed Price Contractor				
SUB:01	Mobilization & Preparatory	69,430	68,250	75,120
SUB:02	Monitoring, Sampling & Analysis	219,350	88,710	303,450
SUB:08	Solids Collection & Containment	456,380	233,580	525,740
SUB:13	Physical Treatment	-	-	1,611,480
SUB:14	Thermal Treatment	-	-	-
SUB:15	Stabilization/Fixation	-	27,873,720	-
SUB:18	Disposal (Other than Commercial)	5,895,520	-	4,750,350
SUB:20	Site Restoration	1,145,530	669,110	1,037,890
SUB:21	Demobilization	16,190	16,460	16,170
WHC: Westinghouse Hanford Company				
WHC:02	Monitoring, Sampling & Analysis	399,560	2,256,070	626,660
WHC:08	Solids Collection & Containment	39,740	370,950	61,200
Subcontractor Materials Procurement Rate		78,110	289,500	83,200
Project Management/Construction Management		1,249,330	4,779,950	1,363,690
General & Admin/Common Support Pool		2,442,430	9,344,810	2,666,010
Contingency		4,188,630	15,636,980	5,063,490
Total		16,508,130	61,628,090	18,748,610
Capital		16,508,130	33,886,890	17,295,880
Annual Operations & Maintenance		0	7,300,316	1,452,730
Present Worth		15,725,648	54,806,062	17,866,453

SS-3/SW-3: Containment
SS-4/SW-4: Removal/Disposal
SS-8A/SS-8B/SW-7: In Situ Treatment
SS-10/SW-9: Removal/Treatment/Disposal

Table B-5 Cost Summary for Pluto Cribs

Cost Element		SS-4	SS-8A	SS-10
ANA: Offsite Analytical Services				
ANA:02	Monitoring, Sampling & Analysis	16,840	-	29,470
SUB: Fixed Price Contractor				
SUB:01	Mobilization & Preparatory	53,120	45,040	53,600
SUB:02	Monitoring, Sampling & Analysis	1,540	960	1,670
SUB:08	Solids Collection & Containment	6,590	6,040	7,560
SUB:13	Physical Treatment	-	-	171,110
SUB:14	Thermal Treatment	-	-	-
SUB:15	Stabilization/Fixation	-	225,280	-
SUB:18	Disposal (Other than Commercial)	16,960	-	10,090
SUB:20	Site Restoration	19,870	18,640	19,480
SUB:21	Demobilization	13,110	13,120	13,210
WHC: Westinghouse Hanford Company				
WHC:02	Monitoring, Sampling & Analysis	10,030	22,110	41,410
WHC:08	Solids Collection & Containment	280	1,550	3,870
Subcontractor Materials Procurement Rate		8,120	22,560	20,200
Project Management/Construction Management		19,440	53,300	51,330
General & Admin/Common Support Pool		38,010	104,190	100,350
Contingency		73,410	174,350	193,640
Total		277,310	687,150	716,990
Capital		277,310	597,530	707,750
Annual Operations & Maintenance		0	89,620	9,240
Present Worth		266,639	660,573	692,246

SS-3/SW-3: Containment
SS-4/SW-4: Removal/Disposal
SS-8A/SS-8B/SW-7: In Situ Treatment
SS-10/SW-9: Removal/Treatment/Disposal

Table B-6 Cost Summary for Dummy Decontamination Cribs and French Drains

Cost Element		SS-3	SS-4	SS-8A	SS-10
ANA: Offsite Analytical Services					
ANA:02	Monitoring, Sampling & Analysis	-	16,840	-	29,470
SUB: Fixed Price Contractor					
SUB:01	Mobilization & Preparatory	43,140	52,730	44,520	52,660
SUB:02	Monitoring, Sampling & Analysis	-	2,680	1,840	2,780
SUB:08	Solids Collection & Containment	108,570	7,700	8,130	9,270
SUB:13	Physical Treatment	-	-	-	171,630
SUB:14	Thermal Treatment	-	-	-	-
SUB:15	Stabilization/Fixation	-	-	247,890	-
SUB:18	Disposal (Other than Commercial)	-	20,150	-	11,410
SUB:20	Site Restoration	15,770	21,100	19,480	20,340
SUB:21	Demobilization	13,030	13,060	13,030	13,020
WHC: Westinghouse Hanford Company					
WHC:02	Monitoring, Sampling & Analysis	13,470	12,060	23,970	44,080
WHC:08	Solids Collection & Containment	250	560	1,830	4,220
Subcontractor Materials Procurement Rate		13,180	8,570	24,450	20,520
Project Management/Construction Management		31,110	20,790	57,770	52,490
General & Admin/Common Support Pool		60,820	40,650	112,940	102,620
Contingency		101,770	78,080	188,990	197,770
Total		401,110	294,980	744,850	732,280
Capital		401,110	294,980	632,340	720,850
Annual Operations & Maintenance		5,429	0	112,510	11,430
Present Worth		453,805	283,449	715,494	706,693

SS-3/SW-3: Containment
SS-4/SW-4: Removal/Disposal
SS-8A/SS-8B/SW-7: In Situ Treatment
SS-10/SW-9: Removal/Treatment/Disposal

Table B-7 Cost Summary for Pipelines

Cost Element		SS-3	SS-4	SS-8B	SS-10
ANA: Offsite Analytical Services					
ANA:02	Monitoring, Sampling & Analysis	-	412,580	-	766,220
SUB: Fixed Price Contractor					
SUB:01	Mobilization & Preparatory	27,890	47,282	27,710	47,280
SUB:02	Monitoring, Sampling & Analysis	-	935,521	-	1,014,990
SUB:08	Solids Collection & Containment	20,751,680	2,793,691	3,372,720	2,812,350
SUB:13	Physical Treatment	-	-	-	5,933,280
SUB:14	Thermal Treatment	-	-	-	-
SUB:15	Stabilization/Fixation	-	-	-	-
SUB:18	Disposal (Other than Commercial)	-	7,994,662	-	5,912,960
SUB:20	Site Restoration	2,384,460	4,115,948	68,530	3,951,860
SUB:21	Demobilization	8,680	10,984	8,620	10,980
WHC: Westinghouse Hanford Company					
WHC:02	Monitoring, Sampling & Analysis	897,000	1,565,798	120,110	1,565,930
WHC:08	Solids Collection & Containment	22,000	219,825	8,800	216,660
Subcontractor Materials Procurement Rate		231,730	158,981	34,780	196,840
Project Management/Construction Management		3,648,510	2,676,404	546,190	3,249,470
General & Admin/Common Support Pool		7,132,850	5,232,369	1,067,800	6,352,710
Contingency		11,935,630	9,942,337	1,786,790	11,851,670
Total		47,040,420	36,106,381	7,042,050	43,883,200
Capital		47,040,420	36,106,381	7,042,050	38,108,100
Annual Operations & Maintenance		1,037,584	0	168,636	2,310,040
Present Worth		54,579,112	32,948,740	8,874,465	40,025,889

SS-3/SW-3: Containment
SS-4/SW-4: Removal/Disposal
SS-8A/SS-8B/SW-7: In Situ Treatment
SS-10/SW-9: Removal/Treatment/Disposal

Table B-8 Cost Summary for Burial Grounds

Cost Element		SW-3	SW-4	SW-7	SW-9
ANA: Offsite Analytical Services					
ANA:02	Monitoring, Sampling & Analysis	-	12,630	-	12,630
SUB: Fixed Price Contractor					
SUB:01	Mobilization & Preparatory	50,190	53,490	75,820	60,410
SUB:02	Monitoring, Sampling & Analysis	-	30,430	-	30,420
SUB:08	Solids Collection & Containment	447,140	75,620	500,890	75,610
SUB:13	Physical Treatment	-	-	-	87,220
SUB:14	Thermal Treatment	-	-	-	278,830
SUB:15	Stabilization/Fixation	-	-	-	-
SUB:18	Disposal (Other than Commercial)	-	767,640	-	446,340
SUB:20	Site Restoration	49,460	173,970	49,490	172,910
SUB:21	Demobilization	14,030	14,010	14,040	14,010
WHC: Westinghouse Hanford Company					
WHC:02	Monitoring, Sampling & Analysis	28,220	52,580	50,490	66,960
WHC:08	Solids Collection & Containment	740	6,330	3,170	11,400
Subcontractor Materials Procurement Rate		40,940	81,410	46,740	85,100
Project Management/Construction Management		94,610	188,320	111,090	199,380
General & Admin/Common Support Pool		184,960	368,170	217,190	389,790
Contingency		309,490	675,100	363,430	714,480
Total		1,219,770	2,499,700	1,432,340	2,645,500
Capital		1,219,770	2,499,700	1,432,340	2,508,630
Annual Operations & Maintenance		22,357	0	25,044	136,870
Present Worth		1,451,296	2,383,260	1, 689,485	2,532,877

SS-3/SW-3: Containment
SS-4/SW-4: Removal/Disposal
SS-8A/SS-8B/SW-7: In Situ Treatment
SS-10/SW-9: Removal/Treatment/Disposal

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